

Project:				Project No:		
March Hywel				C1447		
Calcs By:	Chck'd:	Date:	Rev:	Page No.		
TAH	-	08/11/2020	0	2/1		
Ref:	Calcs For: <u>Retaining Wall Desing</u>					Notes
	The calculations within the following section of this submission relate to the design of the retaining walls are Mach Hywel. The calculations included are for all walls exceeding 1.5m. Walls have all been detailed as shown on drawing C1447-S001 to 004, with land drains and or wheep holes. RC Walls are RC35 concrete, with B500B reinforcement All Masonry walls are 10.4N block with a Type (ii) mortar designation, on Mass concrete bases of GEN3 concrete. The founding strata is sandstone bedrock.					

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 7				Start page no./Revision 2 2	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

RETAINING WALL ANALYSIS

In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1

Tedds calculation version 2.9.11

Retaining wall details

Stem type	Cantilever
Stem height	$h_{\text{stem}} = 3250 \text{ mm}$
Stem thickness	$t_{\text{stem}} = 300 \text{ mm}$
Angle to rear face of stem	$\alpha = 90 \text{ deg}$
Stem density	$\gamma_{\text{stem}} = 25 \text{ kN/m}^3$
Toe length	$l_{\text{toe}} = 2150 \text{ mm}$
Heel length	$l_{\text{heel}} = 450 \text{ mm}$
Base thickness	$t_{\text{base}} = 350 \text{ mm}$
Base density	$\gamma_{\text{base}} = 25 \text{ kN/m}^3$
Height of retained soil	$h_{\text{ret}} = 2500 \text{ mm}$
Angle of soil surface	$\beta = 38 \text{ deg}$
Depth of cover	$d_{\text{cover}} = 750 \text{ mm}$
Depth of excavation	$d_{\text{exc}} = 100 \text{ mm}$

Retained soil properties

Soil type	Medium dense well graded sand and gravel
Moist density	$\gamma_{\text{mr}} = 19 \text{ kN/m}^3$
Saturated density	$\gamma_{\text{sr}} = 21 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{\text{r.k}} = 36 \text{ deg}$
Characteristic wall friction angle	$\delta_{\text{r.k}} = 18 \text{ deg}$

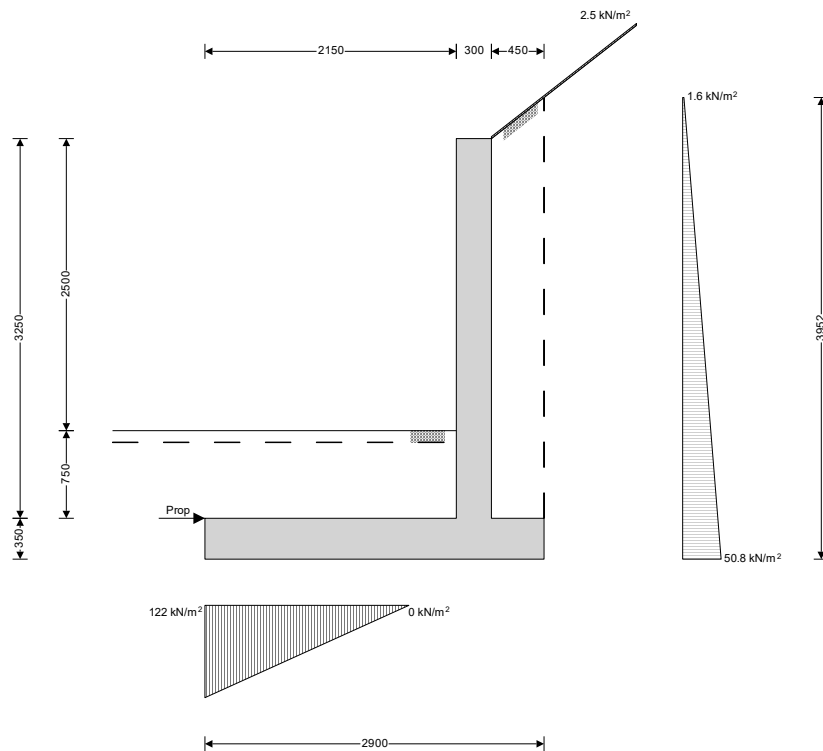
Base soil properties

Soil type	Medium dense rock fill
Soil density	$\gamma_{\text{b}} = 16.3 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{\text{b.k}} = 36 \text{ deg}$
Characteristic wall friction angle	$\delta_{\text{b.k}} = 18 \text{ deg}$
Characteristic base friction angle	$\delta_{\text{bb.k}} = 30 \text{ deg}$
Presumed bearing capacity	$P_{\text{bearing}} = 170 \text{ kN/m}^2$

Loading details

Variable surcharge load	Surcharge _Q = 2.5 kN/m²
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Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 7				Start page no./Revision 2 3	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date



General arrangement

Calculate retaining wall geometry

Base length

$$l_{base} = l_{toe} + t_{stem} + l_{heel} = 2900 \text{ mm}$$

Moist soil height

$$h_{moist} = h_{soil} = 3250 \text{ mm}$$

Length of surcharge load

$$l_{sur} = l_{heel} = 450 \text{ mm}$$

- Distance to vertical component

$$x_{sur_v} = l_{base} - l_{heel} / 2 = 2675 \text{ mm}$$

Effective height of wall

$$h_{eff} = h_{base} + d_{cover} + h_{ret} + l_{sur} * \tan(\beta) = 3952 \text{ mm}$$

- Distance to horizontal component

$$x_{sur_h} = h_{eff} / 2 = 1976 \text{ mm}$$

Area of wall stem

$$A_{stem} = h_{stem} * t_{stem} = 0.975 \text{ m}^2$$

- Distance to vertical component

$$x_{stem} = l_{toe} + t_{stem} / 2 = 2300 \text{ mm}$$

Area of wall base

$$A_{base} = l_{base} * t_{base} = 1.015 \text{ m}^2$$

- Distance to vertical component

$$x_{base} = l_{base} / 2 = 1450 \text{ mm}$$

Area of moist soil

$$A_{moist} = h_{moist} * l_{heel} + \tan(\beta) * l_{heel}^2 / 2 = 1.542 \text{ m}^2$$

- Distance to vertical component

$$x_{moist_v} = l_{base} - (h_{moist} * l_{heel}^2 / 2 + \tan(\beta) * l_{heel}^3 / 6) / A_{moist} = 2679 \text{ mm}$$

- Distance to horizontal component

$$x_{moist_h} = h_{eff} / 3 = 1317 \text{ mm}$$

Area of base soil

$$A_{pass} = d_{cover} * l_{toe} = 1.612 \text{ m}^2$$

- Distance to vertical component

$$x_{pass_v} = l_{base} - (d_{cover} * l_{toe} * (l_{base} - l_{toe} / 2)) / A_{pass} = 1075 \text{ mm}$$

- Distance to horizontal component

$$x_{pass_h} = (d_{cover} + h_{base}) / 3 = 367 \text{ mm}$$

Area of excavated base soil

$$A_{exc} = h_{pass} * l_{toe} = 1.398 \text{ m}^2$$

- Distance to vertical component

$$x_{exc_v} = l_{base} - (h_{pass} * l_{toe} * (l_{base} - l_{toe} / 2)) / A_{exc} = 1075 \text{ mm}$$

- Distance to horizontal component

$$x_{exc_h} = (h_{pass} + h_{base}) / 3 = 333 \text{ mm}$$

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r.k})^2 / (\sin(\alpha)^2 * \sin(\alpha - \delta'_{r.k})) = 0.688$$

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 7				Start page no./Revision 2 4	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,k})^2 / (\sin(90 + \delta_{b,k}) * [1 - \sqrt{[\sin(\phi'_{b,k} + \delta_{b,k}) * \sin(\phi'_{b,k}) / (\sin(90 + \delta_{b,k}))]}])^2 = \mathbf{8.022}$$

Bearing pressure check

Vertical forces on wall

Wall stem	$F_{stem} = A_{stem} * \gamma_{stem} = \mathbf{24.4 \text{ kN/m}}$
Wall base	$F_{base} = A_{base} * \gamma_{base} = \mathbf{25.4 \text{ kN/m}}$
Surcharge load	$F_{sur_v} = \text{Surcharge}_Q * l_{heel} = \mathbf{1.1 \text{ kN/m}}$
Moist retained soil	$F_{moist_v} = A_{moist} * \gamma_{mr} = \mathbf{29.3 \text{ kN/m}}$
Base soil	$F_{pass_v} = A_{pass} * \gamma_b = \mathbf{26.2 \text{ kN/m}}$
Total	$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} + F_{pass_v} = \mathbf{106.4 \text{ kN/m}}$

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A * \cos(\delta_{r,k}) * \text{Surcharge}_Q * h_{eff} = \mathbf{6.5 \text{ kN/m}}$
Moist retained soil	$F_{moist_h} = K_A * \cos(\delta_{r,k}) * \gamma_{mr} * h_{eff}^2 / 2 = \mathbf{97.1 \text{ kN/m}}$
Base soil	$F_{pass_h} = -K_P * \cos(\delta_{b,k}) * \gamma_b * (d_{cover} + h_{base})^2 / 2 = \mathbf{-75 \text{ kN/m}}$
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{pass_h} = \mathbf{28.5 \text{ kN/m}}$

Moments on wall

Wall stem	$M_{stem} = F_{stem} * x_{stem} = \mathbf{56.1 \text{ kNm/m}}$
Wall base	$M_{base} = F_{base} * x_{base} = \mathbf{36.8 \text{ kNm/m}}$
Surcharge load	$M_{sur} = F_{sur_v} * x_{sur_v} - F_{sur_h} * x_{sur_h} = \mathbf{-9.8 \text{ kNm/m}}$
Moist retained soil	$M_{moist} = F_{moist_v} * x_{moist_v} - F_{moist_h} * x_{moist_h} = \mathbf{-49.4 \text{ kNm/m}}$
Base soil	$M_{pass} = F_{pass_v} * x_{pass_v} = \mathbf{28.2 \text{ kNm/m}}$
Total	$M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} = \mathbf{61.8 \text{ kNm/m}}$

Check bearing pressure

Propping force	$F_{prop_base} = F_{total_h} = \mathbf{28.5 \text{ kN/m}}$
Distance to reaction	$\bar{x} = M_{total} / F_{total_v} = \mathbf{581 \text{ mm}}$
Eccentricity of reaction	$e = \bar{x} - l_{base} / 2 = \mathbf{-869 \text{ mm}}$
Loaded length of base	$l_{load} = 3 * \bar{x} = \mathbf{1744 \text{ mm}}$
Bearing pressure at toe	$q_{toe} = 2 * F_{total_v} / l_{load} = \mathbf{122 \text{ kN/m}^2}$
Bearing pressure at heel	$q_{heel} = \mathbf{0 \text{ kN/m}^2}$
Factor of safety	$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = \mathbf{1.394}$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

RETAINING WALL DESIGN

In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the UK National Annex incorporating National Amendment No.1

Tedds calculation version 2.9.11

Concrete details - Table 3.1 - Strength and deformation characteristics for concrete

Concrete strength class	C32/40
Characteristic compressive cylinder strength	$f_{ck} = \mathbf{32 \text{ N/mm}^2}$
Characteristic compressive cube strength	$f_{ck,cube} = \mathbf{40 \text{ N/mm}^2}$
Mean value of compressive cylinder strength	$f_{cm} = f_{ck} + 8 \text{ N/mm}^2 = \mathbf{40 \text{ N/mm}^2}$
Mean value of axial tensile strength	$f_{ctm} = 0.3 \text{ N/mm}^2 * (f_{ck} / 1 \text{ N/mm}^2)^{2/3} = \mathbf{3.0 \text{ N/mm}^2}$
5% fractile of axial tensile strength	$f_{ctk,0.05} = 0.7 * f_{ctm} = \mathbf{2.1 \text{ N/mm}^2}$
Secant modulus of elasticity of concrete	$E_{cm} = 22 \text{ kN/mm}^2 * (f_{cm} / 10 \text{ N/mm}^2)^{0.3} = \mathbf{33346 \text{ N/mm}^2}$
Partial factor for concrete - Table 2.1N	$\gamma_C = \mathbf{1.50}$

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 7				Start page no./Revision 2 5	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

Compressive strength coefficient - cl.3.1.6(1)

$$\alpha_{cc} = 0.85$$

Design compressive concrete strength - exp.3.15

$$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_c = 18.1 \text{ N/mm}^2$$

Maximum aggregate size

$$h_{agg} = 20 \text{ mm}$$

Ultimate strain - Table 3.1

$$\epsilon_{cu2} = 0.0035$$

Shortening strain - Table 3.1

$$\epsilon_{cu3} = 0.0035$$

Effective compression zone height factor

$$\lambda = 0.80$$

Effective strength factor

$$\eta = 1.00$$

Bending coefficient k_1

$$K_1 = 0.40$$

Bending coefficient k_2

$$K_2 = 1.00 * (0.6 + 0.0014/\epsilon_{cu2}) = 1.00$$

Bending coefficient k_3

$$K_3 = 0.40$$

Bending coefficient k_4

$$K_4 = 1.00 * (0.6 + 0.0014/\epsilon_{cu2}) = 1.00$$

Reinforcement details

Characteristic yield strength of reinforcement

$$f_{yk} = 500 \text{ N/mm}^2$$

Modulus of elasticity of reinforcement

$$E_s = 200000 \text{ N/mm}^2$$

Partial factor for reinforcing steel - Table 2.1N

$$\gamma_s = 1.15$$

Design yield strength of reinforcement

$$f_{yd} = f_{yk} / \gamma_s = 435 \text{ N/mm}^2$$

Cover to reinforcement

Front face of stem

$$c_{sf} = 40 \text{ mm}$$

Rear face of stem

$$c_{sr} = 50 \text{ mm}$$

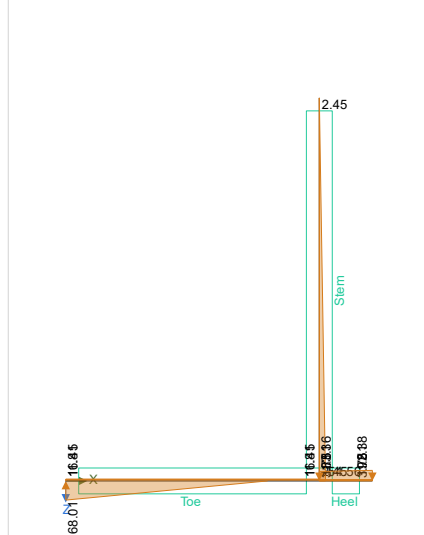
Top face of base

$$c_{bt} = 50 \text{ mm}$$

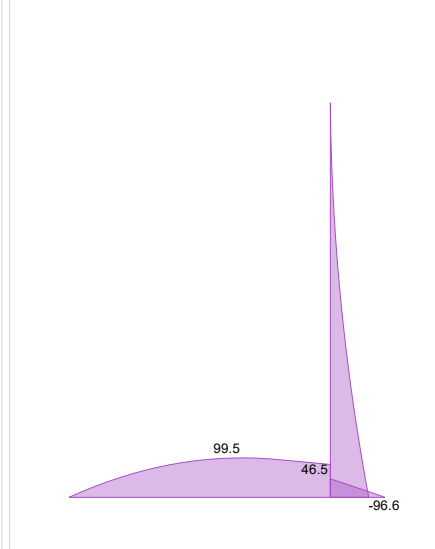
Bottom face of base

$$c_{bb} = 50 \text{ mm}$$

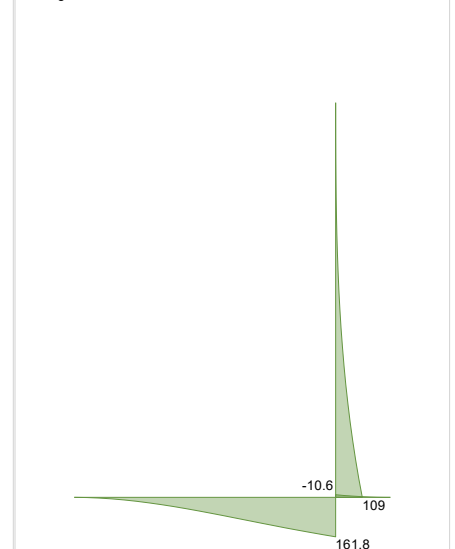
Loading details - Combination No.1 - kN/m



Shear force - Combination No.1 - kN/m

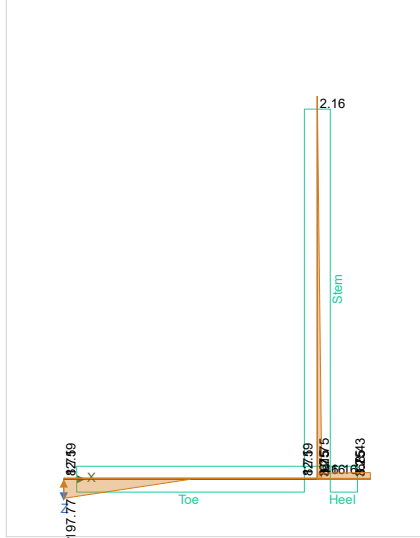


Bending moment - Combination No.1 - kNm/m

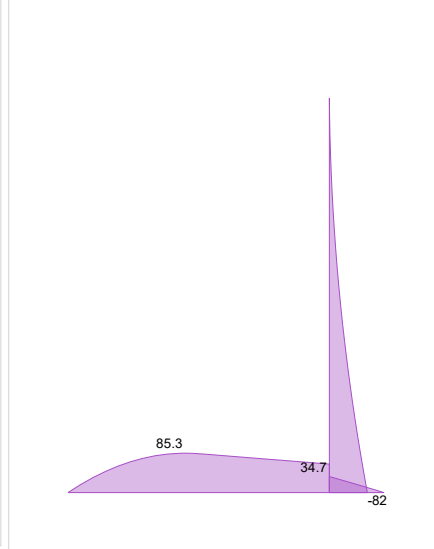


Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 7				Start page no./Revision 2 6	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

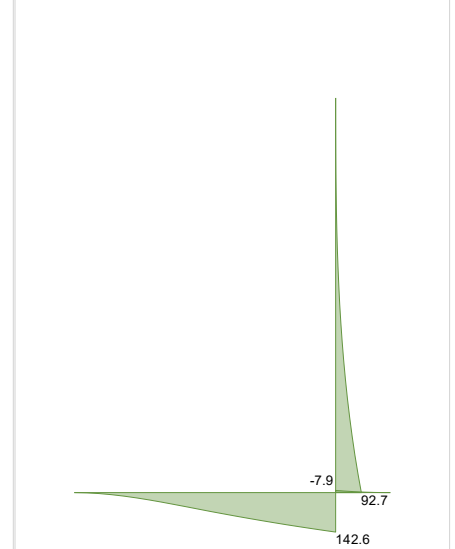
Loading details - Combination No.2 - kN/m



Shear force - Combination No.2 - kN/m



Bending moment - Combination No.2 - kNm/m



Check stem design at base of stem

Depth of section

$h = 300 \text{ mm}$

Rectangular section in flexure - Section 6.1

Design bending moment combination 1

$M = 109 \text{ kNm/m}$

Depth to tension reinforcement

$d = h - c_{sr} - \phi_{sr} / 2 = 242 \text{ mm}$

$K = M / (d^2 \times f_{ck}) = 0.058$

$K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$

$K' = 0.207$

$K' > K$ - No compression reinforcement is required

Lever arm

$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d = 229 \text{ mm}$

Depth of neutral axis

$x = 2.5 \times (d - z) = 33 \text{ mm}$

Area of tension reinforcement required

$A_{sr,req} = M / (f_{yd} \times z) = 1096 \text{ mm}^2/\text{m}$

Tension reinforcement provided

16 dia.bars @ 100 c/c

Area of tension reinforcement provided

$A_{sr,prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) = 2011 \text{ mm}^2/\text{m}$

Minimum area of reinforcement - exp.9.1N

$A_{sr,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 381 \text{ mm}^2/\text{m}$

Maximum area of reinforcement - cl.9.2.1.1(3)

$A_{sr,max} = 0.04 \times h = 12000 \text{ mm}^2/\text{m}$

$\max(A_{sr,req}, A_{sr,min}) / A_{sr,prov} = 0.545$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Deflection control - Section 7.4

Reference reinforcement ratio

$\rho_0 = \sqrt{(f_{ck} / 1 \text{ N/mm}^2)} / 1000 = 0.006$

Required tension reinforcement ratio

$\rho = A_{sr,req} / d = 0.005$

Required compression reinforcement ratio

$\rho' = A_{sr,2,req} / d_2 = 0.000$

Structural system factor - Table 7.4N

$K_b = 0.4$

Reinforcement factor - exp.7.17

$K_s = \min(500 \text{ N/mm}^2 / (f_{yk} \times A_{sr,req} / A_{sr,prov}), 1.5) = 1.5$

Limiting span to depth ratio - exp.7.16.a

$\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1 \text{ N/mm}^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1 \text{ N/mm}^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b) = 14.3$

Actual span to depth ratio

$h_{stem} / d = 13.4$

PASS - Span to depth ratio is less than deflection control limit

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 7				Start page no./Revision 2 7	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

Crack control - Section 7.3

Limiting crack width	$w_{max} = 0.4 \text{ mm}$
Variable load factor - EN1990 – Table A1.1	$\psi_2 = 0.6$
Serviceability bending moment	$M_{sls} = 76.3 \text{ kNm/m}$
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sr,prov} * z) = 165.9 \text{ N/mm}^2$
Load duration	Long term
Load duration factor	$k_t = 0.4$
Effective area of concrete in tension	$A_{c,eff} = \min(2.5 * (h - d), (h - x) / 3, h / 2)$ $A_{c,eff} = 89055 \text{ mm}^2/\text{m}$
Mean value of concrete tensile strength	$f_{ct,eff} = f_{ctm} = 3.0 \text{ N/mm}^2$
Reinforcement ratio	$\rho_{p,eff} = A_{sr,prov} / A_{c,eff} = 0.023$
Modular ratio	$\alpha_e = E_s / E_{cm} = 5.998$
Bond property coefficient	$k_1 = 0.8$
Strain distribution coefficient	$k_2 = 0.5$ $k_3 = 3.4$ $k_4 = 0.425$
Maximum crack spacing - exp.7.11	$s_{r,max} = k_3 * c_{sr} + k_1 * k_2 * k_4 * \phi_{sr} / \rho_{p,eff} = 290 \text{ mm}$
Maximum crack width - exp.7.8	$w_k = s_{r,max} * \max(\sigma_s - k_t * (f_{ct,eff} / \rho_{p,eff}) * (1 + \alpha_e * \rho_{p,eff}), 0.6 * \sigma_s) / E_s$ $w_k = 0.153 \text{ mm}$ $w_k / w_{max} = 0.381$ PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force	$V = 96.6 \text{ kN/m}$ $C_{Rd,c} = 0.18 / \gamma_c = 0.120$ $k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 1.909$
Longitudinal reinforcement ratio	$\rho_l = \min(A_{sr,prov} / d, 0.02) = 0.008$ $v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} * k^{3/2} * f_{ck}^{0.5} = 0.522 \text{ N/mm}^2$
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd,c} = \max(C_{Rd,c} * k * (100 \text{ N}^2/\text{mm}^4 * \rho_l * f_{ck})^{1/3}, v_{min}) * d$ $V_{Rd,c} = 165.5 \text{ kN/m}$ $V / V_{Rd,c} = 0.584$ PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem - Section 9.6

Minimum area of reinforcement – cl.9.6.3(1)	$A_{sx,req} = \max(0.25 * A_{sr,prov}, 0.001 * t_{stem}) = 503 \text{ mm}^2/\text{m}$
Maximum spacing of reinforcement – cl.9.6.3(2)	$s_{sx,max} = 400 \text{ mm}$
Transverse reinforcement provided	10 dia.bars @ 100 c/c
Area of transverse reinforcement provided	$A_{sx,prov} = \pi * \phi_{sx}^2 / (4 * s_{sx}) = 785 \text{ mm}^2/\text{m}$ PASS - Area of reinforcement provided is greater than area of reinforcement required

Check base design at toe

Depth of section	$h = 350 \text{ mm}$
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Rectangular section in flexure - Section 6.1

Design bending moment combination 1	$M = 161.8 \text{ kNm/m}$
Depth to tension reinforcement	$d = h - c_{bb} - \phi_{bb} / 2 = 292 \text{ mm}$ $K = M / (d^2 * f_{ck}) = 0.059$ $K' = (2 * \eta * \alpha_{ec} / \gamma_c) * (1 - \lambda * (\delta - K_1) / (2 * K_2)) * (\lambda * (\delta - K_1) / (2 * K_2))$ $K' = 0.207$

K' > K - No compression reinforcement is required

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 7				Start page no./Revision 2 8	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

Lever arm $z = \min(0.5 + 0.5 * (1 - 2 * K / (\eta * \alpha_{sc} / \gamma_c))^{0.5}, 0.95) * d = \mathbf{276 \text{ mm}}$

Depth of neutral axis $x = 2.5 * (d - z) = \mathbf{40 \text{ mm}}$

Area of tension reinforcement required $A_{bb,req} = M / (f_{yd} * z) = \mathbf{1349 \text{ mm}^2/\text{m}}$

Tension reinforcement provided **16 dia.bars @ 100 c/c**

Area of tension reinforcement provided $A_{bb,prov} = \pi * \phi_{bb}^2 / (4 * s_{bb}) = \mathbf{2011 \text{ mm}^2/\text{m}}$

Minimum area of reinforcement - exp.9.1N $A_{bb,min} = \max(0.26 * f_{ctm} / f_{yk}, 0.0013) * d = \mathbf{459 \text{ mm}^2/\text{m}}$

Maximum area of reinforcement - cl.9.2.1.1(3) $A_{bb,max} = 0.04 * h = \mathbf{14000 \text{ mm}^2/\text{m}}$

$\max(A_{bb,req}, A_{bb,min}) / A_{bb,prov} = \mathbf{0.671}$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width $w_{max} = \mathbf{0.4 \text{ mm}}$

Variable load factor - EN1990 – Table A1.1 $\psi_2 = \mathbf{0.6}$

Serviceability bending moment $M_{sls} = \mathbf{118.5 \text{ kNm/m}}$

Tensile stress in reinforcement $\sigma_s = M_{sls} / (A_{bb,prov} * z) = \mathbf{213.6 \text{ N/mm}^2}$

Load duration Long term

Load duration factor $k_t = \mathbf{0.4}$

Effective area of concrete in tension $A_{c,eff} = \min(2.5 * (h - d), (h - x) / 3, h / 2)$
 $A_{c,eff} = \mathbf{103192 \text{ mm}^2/\text{m}}$

Mean value of concrete tensile strength $f_{ct,eff} = f_{ctm} = \mathbf{3.0 \text{ N/mm}^2}$

Reinforcement ratio $\rho_{p,eff} = A_{bb,prov} / A_{c,eff} = \mathbf{0.019}$

Modular ratio $\alpha_E = E_s / E_{cm} = \mathbf{5.998}$

Bond property coefficient $k_1 = \mathbf{0.8}$

Strain distribution coefficient $k_2 = \mathbf{0.5}$
 $k_3 = \mathbf{3.4}$
 $k_4 = \mathbf{0.425}$

Maximum crack spacing - exp.7.11 $s_{r,max} = k_3 * C_{bb} + k_1 * k_2 * k_4 * \phi_{bb} / \rho_{p,eff} = \mathbf{310 \text{ mm}}$

Maximum crack width - exp.7.8 $w_k = s_{r,max} * \max(\sigma_s - k_t * (f_{ct,eff} / \rho_{p,eff}) * (1 + \alpha_E * \rho_{p,eff}), 0.6 * \sigma_s) / E_s$
 $w_k = \mathbf{0.223 \text{ mm}}$
 $w_k / w_{max} = \mathbf{0.558}$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force $V = \mathbf{99.5 \text{ kN/m}}$
 $C_{Rd,c} = 0.18 / \gamma_c = \mathbf{0.120}$
 $k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{1.828}$

Longitudinal reinforcement ratio $\rho_l = \min(A_{bb,prov} / d, 0.02) = \mathbf{0.007}$
 $v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} * k^{3/2} * f_{ck}^{0.5} = \mathbf{0.489 \text{ N/mm}^2}$

Design shear resistance - exp.6.2a & 6.2b $V_{Rd,c} = \max(C_{Rd,c} * k * (100 \text{ N}^2/\text{mm}^4 * \rho_l * f_{ck})^{1/3}, v_{min}) * d$
 $V_{Rd,c} = \mathbf{179.5 \text{ kN/m}}$
 $V / V_{Rd,c} = \mathbf{0.554}$

PASS - Design shear resistance exceeds design shear force

Check base design at heel

Depth of section $h = \mathbf{350 \text{ mm}}$

Rectangular section in flexure - Section 6.1

Design bending moment combination 1 $M = \mathbf{10.6 \text{ kNm/m}}$

Depth to tension reinforcement $d = h - C_{bt} - \phi_{bt} / 2 = \mathbf{295 \text{ mm}}$

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 7				Start page no./Revision 2 9	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

$$K = M / (d^2 \times f_{ck}) = \mathbf{0.004}$$

$$K' = (2 \times \eta \times \alpha_{ec} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$$

$$K' = \mathbf{0.207}$$

K' > K - No compression reinforcement is required

Lever arm

$$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{ec} / \gamma_c))^{0.5}, 0.95) \times d = \mathbf{280 \text{ mm}}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = \mathbf{37 \text{ mm}}$$

Area of tension reinforcement required

$$A_{bt,req} = M / (f_{yd} \times z) = \mathbf{87 \text{ mm}^2/\text{m}}$$

Tension reinforcement provided

$$10 \text{ dia. bars @ } 100 \text{ c/c}$$

Area of tension reinforcement provided

$$A_{bt,prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt}) = \mathbf{785 \text{ mm}^2/\text{m}}$$

Minimum area of reinforcement - exp.9.1N

$$A_{bt,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{464 \text{ mm}^2/\text{m}}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{bt,max} = 0.04 \times h = \mathbf{14000 \text{ mm}^2/\text{m}}$$

$$\max(A_{bt,req}, A_{bt,min}) / A_{bt,prov} = \mathbf{0.591}$$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width

$$w_{max} = \mathbf{0.4 \text{ mm}}$$

Variable load factor - EN1990 – Table A1.1

$$\psi_E = \mathbf{0.6}$$

Serviceability bending moment

$$M_{sls} = \mathbf{7.7 \text{ kNm/m}}$$

Tensile stress in reinforcement

$$\sigma_s = M_{sls} / (A_{bt,prov} \times z) = \mathbf{35.2 \text{ N/mm}^2}$$

Load duration

Long term

Load duration factor

$$k_t = \mathbf{0.4}$$

Effective area of concrete in tension

$$A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$$

$$A_{c,eff} = \mathbf{104375 \text{ mm}^2/\text{m}}$$

Mean value of concrete tensile strength

$$f_{ct,eff} = f_{ctm} = \mathbf{3.0 \text{ N/mm}^2}$$

Reinforcement ratio

$$\rho_{p,eff} = A_{bt,prov} / A_{c,eff} = \mathbf{0.008}$$

Modular ratio

$$\alpha_E = E_s / E_{cm} = \mathbf{5.998}$$

Bond property coefficient

$$k_1 = \mathbf{0.8}$$

Strain distribution coefficient

$$k_2 = \mathbf{0.5}$$

$$k_3 = \mathbf{3.4}$$

$$k_4 = \mathbf{0.425}$$

Maximum crack spacing - exp.7.11

$$s_{r,max} = k_3 \times C_{bt} + k_1 \times k_2 \times k_4 \times \phi_{bt} / \rho_{p,eff} = \mathbf{396 \text{ mm}}$$

Maximum crack width - exp.7.8

$$w_k = s_{r,max} \times \max(\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_E \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$$

$$w_k = \mathbf{0.042 \text{ mm}}$$

$$w_k / w_{max} = \mathbf{0.104}$$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = \mathbf{46.5 \text{ kN/m}}$$

$$C_{Rd,c} = 0.18 / \gamma_c = \mathbf{0.120}$$

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{1.823}$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{bt,prov} / d, 0.02) = \mathbf{0.003}$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.487 \text{ N/mm}^2}$$

Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$$

$$V_{Rd,c} = \mathbf{143.8 \text{ kN/m}}$$

$$V / V_{Rd,c} = \mathbf{0.324}$$

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 7				Start page no./Revision 2 10	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

Minimum area of reinforcement – cl.9.3.1.1(2)

$$A_{bx.req} = 0.2 * A_{bb.prov} = \mathbf{402 \text{ mm}^2/m}$$

Maximum spacing of reinforcement – cl.9.3.1.1(3)

$$s_{bx.max} = \mathbf{450 \text{ mm}}$$

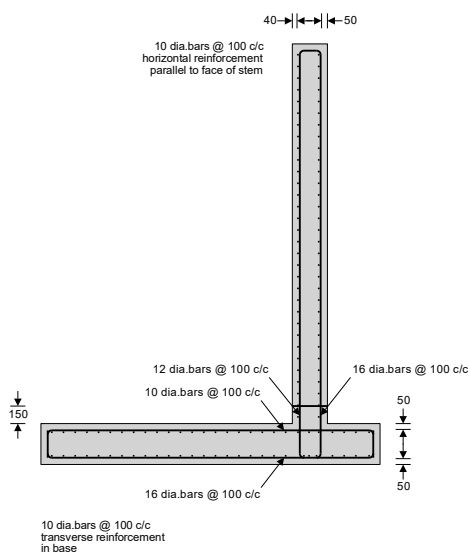
Transverse reinforcement provided

$$10 \text{ dia.bars @ } 100 \text{ c/c}$$

Area of transverse reinforcement provided

$$A_{bx.prov} = \pi * \phi_{bx}^2 / (4 * s_{bx}) = \mathbf{785 \text{ mm}^2/m}$$

PASS - Area of reinforcement provided is greater than area of reinforcement required



Reinforcement details

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 5				Start page no./Revision 2 11	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

RETAINING WALL ANALYSIS

In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1

Tedds calculation version 2.9.11

Retaining wall details

Stem type	Cantilever
Stem height	$h_{\text{stem}} = 2300 \text{ mm}$
Stem thickness	$t_{\text{stem}} = 250 \text{ mm}$
Angle to rear face of stem	$\alpha = 90 \text{ deg}$
Stem density	$\gamma_{\text{stem}} = 25 \text{ kN/m}^3$
Toe length	$l_{\text{toe}} = 150 \text{ mm}$
Heel length	$l_{\text{heel}} = 1100 \text{ mm}$
Base thickness	$t_{\text{base}} = 350 \text{ mm}$
Base density	$\gamma_{\text{base}} = 25 \text{ kN/m}^3$
Height of retained soil	$h_{\text{ret}} = 1950 \text{ mm}$
Angle of soil surface	$\beta = 0 \text{ deg}$
Depth of cover	$d_{\text{cover}} = 250 \text{ mm}$
Depth of excavation	$d_{\text{exc}} = 100 \text{ mm}$

Retained soil properties

Soil type	Medium dense well graded sand and gravel
Moist density	$\gamma_{\text{mr}} = 20 \text{ kN/m}^3$
Saturated density	$\gamma_{\text{sr}} = 22.3 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{\text{r.k}} = 36 \text{ deg}$
Characteristic wall friction angle	$\delta_{\text{r.k}} = 18 \text{ deg}$

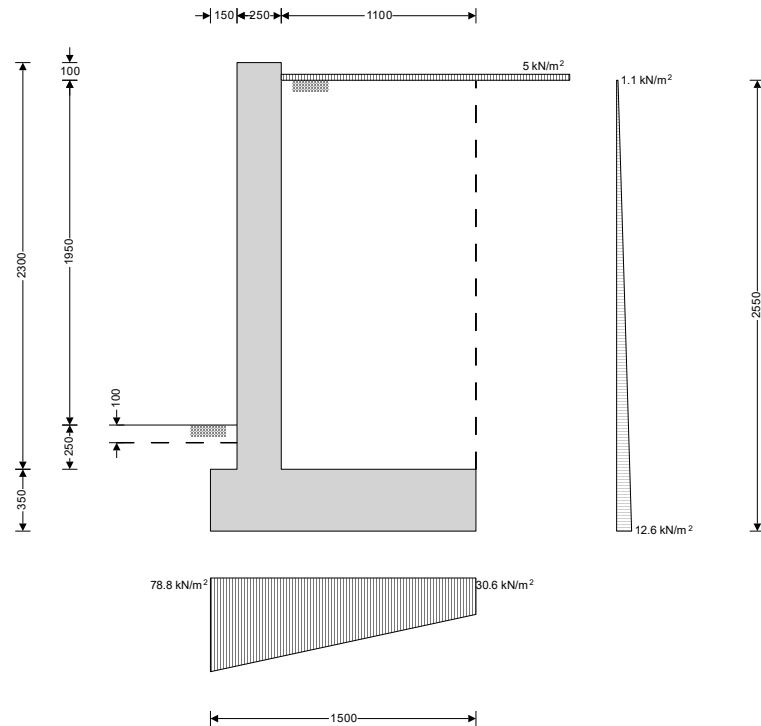
Base soil properties

Soil type	Medium dense rock fill
Soil density	$\gamma_{\text{b}} = 16.3 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{\text{b.k}} = 36 \text{ deg}$
Characteristic wall friction angle	$\delta_{\text{b.k}} = 18 \text{ deg}$
Characteristic base friction angle	$\delta_{\text{bb.k}} = 30 \text{ deg}$
Presumed bearing capacity	$P_{\text{bearing}} = 150 \text{ kN/m}^2$

Loading details

Variable surcharge load	Surcharge _Q = 5 kN/m ²
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Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 5				Start page no./Revision 2 12	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date



General arrangement

Calculate retaining wall geometry

Base length

$$l_{base} = l_{toe} + t_{stem} + l_{heel} = 1500 \text{ mm}$$

Moist soil height

$$h_{moist} = h_{soil} = 2200 \text{ mm}$$

Length of surcharge load

$$l_{sur} = l_{heel} = 1100 \text{ mm}$$

- Distance to vertical component

$$x_{sur_v} = l_{base} - l_{heel} / 2 = 950 \text{ mm}$$

Effective height of wall

$$h_{eff} = h_{base} + d_{cover} + h_{ret} = 2550 \text{ mm}$$

- Distance to horizontal component

$$x_{sur_h} = h_{eff} / 2 = 1275 \text{ mm}$$

Area of wall stem

$$A_{stem} = h_{stem} * t_{stem} = 0.575 \text{ m}^2$$

- Distance to vertical component

$$x_{stem} = l_{toe} + t_{stem} / 2 = 275 \text{ mm}$$

Area of wall base

$$A_{base} = l_{base} * t_{base} = 0.525 \text{ m}^2$$

- Distance to vertical component

$$x_{base} = l_{base} / 2 = 750 \text{ mm}$$

Area of moist soil

$$A_{moist} = h_{moist} * l_{heel} = 2.42 \text{ m}^2$$

- Distance to vertical component

$$x_{moist_v} = l_{base} - (h_{moist} * l_{heel}^2 / 2) / A_{moist} = 950 \text{ mm}$$

- Distance to horizontal component

$$x_{moist_h} = h_{eff} / 3 = 850 \text{ mm}$$

Area of base soil

$$A_{pass} = d_{cover} * l_{toe} = 0.038 \text{ m}^2$$

- Distance to vertical component

$$x_{pass_v} = l_{base} - (d_{cover} * l_{toe} * (l_{base} - l_{toe} / 2)) / A_{pass} = 75 \text{ mm}$$

- Distance to horizontal component

$$x_{pass_h} = (d_{cover} + h_{base}) / 3 = 200 \text{ mm}$$

Area of excavated base soil

$$A_{exc} = h_{pass} * l_{toe} = 0.023 \text{ m}^2$$

- Distance to vertical component

$$x_{exc_v} = l_{base} - (h_{pass} * l_{toe} * (l_{base} - l_{toe} / 2)) / A_{exc} = 75 \text{ mm}$$

- Distance to horizontal component

$$x_{exc_h} = (h_{pass} + h_{base}) / 3 = 167 \text{ mm}$$

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 5				Start page no./Revision 2 13	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 * \sin(\alpha - \delta_{r,k}) * [1 + \sqrt{[\sin(\phi'_{r,k} + \delta_{r,k}) * \sin(\phi'_{r,k} - \beta) / (\sin(\alpha - \delta_{r,k}) * \sin(\alpha + \beta))]}]) = \mathbf{0.236}$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,k})^2 / (\sin(90 + \delta_{b,k}) * [1 - \sqrt{[\sin(\phi'_{b,k} + \delta_{b,k}) * \sin(\phi'_{b,k}) / (\sin(90 + \delta_{b,k}))]}]) = \mathbf{8.022}$$

Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{stem} = A_{stem} * \gamma_{stem} = \mathbf{14.4 \text{ kN/m}}$$

Wall base

$$F_{base} = A_{base} * \gamma_{base} = \mathbf{13.1 \text{ kN/m}}$$

Surcharge load

$$F_{sur_v} = \text{Surcharge}_Q * l_{heel} = \mathbf{5.5 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = A_{moist} * \gamma_{mr} = \mathbf{48.4 \text{ kN/m}}$$

Base soil

$$F_{pass_v} = A_{pass} * \gamma_b = \mathbf{0.6 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} + F_{pass_v} = \mathbf{82 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A * \cos(\delta_{r,k}) * \text{Surcharge}_Q * h_{eff} = \mathbf{2.9 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = K_A * \cos(\delta_{r,k}) * \gamma_{mr} * h_{eff}^2 / 2 = \mathbf{14.6 \text{ kN/m}}$$

Base soil

$$F_{pass_h} = \max(-K_P * \cos(\delta_{b,k}) * \gamma_b * (d_{cover} + h_{base})^2 / 2, -(F_{moist_h} + F_{sur_h})) = \mathbf{-17.5 \text{ kN/m}}$$

Total

$$F_{total_h} = \max(F_{sur_h} + F_{moist_h} + F_{pass_h} - F_{total_v} * \tan(\delta_{bb,k}), 0 \text{ kN/m}) = \mathbf{0 \text{ kN/m}}$$

Moments on wall

Wall stem

$$M_{stem} = F_{stem} * x_{stem} = \mathbf{4 \text{ kNm/m}}$$

Wall base

$$M_{base} = F_{base} * x_{base} = \mathbf{9.8 \text{ kNm/m}}$$

Surcharge load

$$M_{sur} = F_{sur_v} * x_{sur_v} - F_{sur_h} * x_{sur_h} = \mathbf{1.6 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist} = F_{moist_v} * x_{moist_v} - F_{moist_h} * x_{moist_h} = \mathbf{33.6 \text{ kNm/m}}$$

Base soil

$$M_{pass} = F_{pass_v} * x_{pass_v} - F_{pass_h} * x_{pass_h} = \mathbf{3.5 \text{ kNm/m}}$$

Total

$$M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} = \mathbf{52.5 \text{ kNm/m}}$$

Check bearing pressure

Distance to reaction

$$\bar{x} = M_{total} / F_{total_v} = \mathbf{640 \text{ mm}}$$

Eccentricity of reaction

$$e = \bar{x} - l_{base} / 2 = \mathbf{-110 \text{ mm}}$$

Loaded length of base

$$l_{load} = l_{base} = \mathbf{1500 \text{ mm}}$$

Bearing pressure at toe

$$q_{toe} = F_{total_v} / l_{base} * (1 - 6 * e / l_{base}) = \mathbf{78.8 \text{ kN/m}^2}$$

Bearing pressure at heel

$$q_{heel} = F_{total_v} / l_{base} * (1 + 6 * e / l_{base}) = \mathbf{30.6 \text{ kN/m}^2}$$

Factor of safety

$$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = \mathbf{1.905}$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

Partial factors on actions - Table A.3 - Combination 1

Partial factor set

$$A1$$

Permanent unfavourable action

$$\gamma_G = \mathbf{1.35}$$

Permanent favourable action

$$\gamma_{Gf} = \mathbf{1.00}$$

Variable unfavourable action

$$\gamma_Q = \mathbf{1.50}$$

Variable favourable action

$$\gamma_{Qf} = \mathbf{0.00}$$

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 5				Start page no./Revision 2 14	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

Partial factors for soil parameters – Table A.4 - Combination 1

Soil parameter set	M1
Angle of shearing resistance	$\gamma_{\phi'} = 1.00$
Effective cohesion	$\gamma_{c'} = 1.00$
Weight density	$\gamma_{\gamma} = 1.00$

Library item Partial factors output

Retained soil properties

Design moist density	$\gamma_{mr'} = \gamma_{mr} / \gamma_{\gamma} = 20 \text{ kN/m}^3$
Design saturated density	$\gamma_{sr'} = \gamma_{sr} / \gamma_{\gamma} = 22.3 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 36 \text{ deg}$
Design wall friction angle	$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = 18 \text{ deg}$

Base soil properties

Design soil density	$\gamma_{b'} = \gamma_b / \gamma_{\gamma} = 16.3 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = 36 \text{ deg}$
Design wall friction angle	$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = 18 \text{ deg}$
Design base friction angle	$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 30 \text{ deg}$
Design effective cohesion	$c'_{b,d} = c'_{b,k} / \gamma_{c'} = 0 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 * \sin(\alpha - \delta_{r,d}) * [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) * \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) * \sin(\alpha + \beta))]}]^2) = 0.236$
Passive pressure coefficient	$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) * [1 - \sqrt{[\sin(\phi'_{b,d} + \delta_{b,d}) * \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))]}]^2) = 8.022$

Sliding check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} * A_{stem} * \gamma_{stem} = 14.4 \text{ kN/m}$
Wall base	$F_{base} = \gamma_{Gf} * A_{base} * \gamma_{base} = 13.1 \text{ kN/m}$
Moist retained soil	$F_{moist_v} = \gamma_{Gf} * A_{moist} * \gamma_{mr'} = 48.4 \text{ kN/m}$
Base soil	$F_{exc_v} = \gamma_{Gf} * A_{exc} * \gamma_{b'} = 0.4 \text{ kN/m}$
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} + F_{exc_v} = 76.3 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A * \cos(\delta_{r,d}) * \gamma_Q * \text{Surcharge}_Q * h_{eff} = 4.3 \text{ kN/m}$
Moist retained soil	$F_{moist_h} = \gamma_G * K_A * \cos(\delta_{r,d}) * \gamma_{mr'} * h_{eff}^2 / 2 = 19.7 \text{ kN/m}$
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} = 24 \text{ kN/m}$

Check stability against sliding

Base soil resistance	$F_{exc_h} = \gamma_{Gf} * K_P * \cos(\delta_{b,d}) * \gamma_{b'} * (h_{pass} + h_{base})^2 / 2 = 15.5 \text{ kN/m}$
Base friction	$F_{friction} = F_{total_v} * \tan(\delta_{bb,d}) = 44 \text{ kN/m}$
Resistance to sliding	$F_{rest} = F_{exc_h} + F_{friction} = 59.5 \text{ kN/m}$
Factor of safety	$FoS_{sl} = F_{rest} / F_{total_h} = 2.479$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} * A_{stem} * \gamma_{stem} = 14.4 \text{ kN/m}$
Wall base	$F_{base} = \gamma_{Gf} * A_{base} * \gamma_{base} = 13.1 \text{ kN/m}$

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 5				Start page no./Revision 2 15	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{\text{Gf}} * A_{\text{moist}} * \gamma_{\text{mr}}' = \mathbf{48.4 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_v} = \gamma_{\text{Gf}} * A_{\text{exc}} * \gamma_b' = \mathbf{0.4 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} + F_{\text{exc}_v} = \mathbf{76.3 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A * \cos(\delta_{r,d}) * \gamma_Q * \text{Surcharge}_Q * h_{\text{eff}} = \mathbf{4.3 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G * K_A * \cos(\delta_{r,d}) * \gamma_{\text{mr}}' * h_{\text{eff}}^2 / 2 = \mathbf{19.7 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_h} = -\gamma_{\text{Gf}} * K_P * \cos(\delta_{b,d}) * \gamma_b' * (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{-15.5 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{exc}_h} = \mathbf{8.5 \text{ kN/m}}$$

Overturning moments on wall

Surcharge load

$$M_{\text{sur}_OT} = F_{\text{sur}_h} * x_{\text{sur}_h} = \mathbf{5.5 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}_OT} = F_{\text{moist}_h} * x_{\text{moist}_h} = \mathbf{16.8 \text{ kNm/m}}$$

Total

$$M_{\text{total}_OT} = M_{\text{sur}_OT} + M_{\text{moist}_OT} = \mathbf{22.2 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{\text{stem}_R} = F_{\text{stem}} * x_{\text{stem}} = \mathbf{4 \text{ kNm/m}}$$

Wall base

$$M_{\text{base}_R} = F_{\text{base}} * x_{\text{base}} = \mathbf{9.8 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}_R} = F_{\text{moist}_v} * x_{\text{moist}_v} = \mathbf{46 \text{ kNm/m}}$$

Base soil

$$M_{\text{exc}_R} = F_{\text{exc}_v} * x_{\text{exc}_v} - F_{\text{exc}_h} * x_{\text{exc}_h} = \mathbf{2.6 \text{ kNm/m}}$$

Total

$$M_{\text{total}_R} = M_{\text{stem}_R} + M_{\text{base}_R} + M_{\text{moist}_R} + M_{\text{exc}_R} = \mathbf{62.4 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$\text{FoS}_{OT} = M_{\text{total}_R} / M_{\text{total}_OT} = \mathbf{2.806}$$

PASS - Maximum restoring moment is greater than overturning moment

Design approach 1

Partial factors on actions - Table A.3 - Combination 2

Partial factor set

A2

Permanent unfavourable action

$$\gamma_G = \mathbf{1.00}$$

Permanent favourable action

$$\gamma_{\text{Gf}} = \mathbf{1.00}$$

Variable unfavourable action

$$\gamma_Q = \mathbf{1.30}$$

Variable favourable action

$$\gamma_{\text{Qf}} = \mathbf{0.00}$$

Partial factors for soil parameters – Table A.4 - Combination 2

Soil parameter set

M2

Angle of shearing resistance

$$\gamma_{\phi'} = \mathbf{1.25}$$

Effective cohesion

$$\gamma_{c'} = \mathbf{1.25}$$

Weight density

$$\gamma_{\gamma} = \mathbf{1.00}$$

Library item Partial factors output

Retained soil properties

Design moist density

$$\gamma_{\text{mr}}' = \gamma_{\text{mr}} / \gamma_{\gamma} = \mathbf{20 \text{ kN/m}^3}$$

Design saturated density

$$\gamma_{\text{sr}}' = \gamma_{\text{sr}} / \gamma_{\gamma} = \mathbf{22.3 \text{ kN/m}^3}$$

Design effective shear resistance angle

$$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = \mathbf{30.2 \text{ deg}}$$

Design wall friction angle

$$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = \mathbf{14.6 \text{ deg}}$$

Base soil properties

Design soil density

$$\gamma_b' = \gamma_b / \gamma_{\gamma} = \mathbf{16.3 \text{ kN/m}^3}$$

Design effective shear resistance angle

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = \mathbf{30.2 \text{ deg}}$$

Design wall friction angle

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = \mathbf{14.6 \text{ deg}}$$

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 5				Start page no./Revision 2 16	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

Design base friction angle

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = \mathbf{24.8 \text{ deg}}$$

Design effective cohesion

$$c'_{b,d} = c'_{b,k} / \gamma_{c'} = \mathbf{0 \text{ kN/m}^2}$$

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 * \sin(\alpha - \delta_{r,d}) * [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) * \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) * \sin(\alpha + \beta))]}])^2 = \mathbf{0.300}$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) * [1 - \sqrt{[\sin(\phi'_{b,d} + \delta_{b,d}) * \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))]}])^2 = \mathbf{4.938}$$

Sliding check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{Gf} * A_{\text{stem}} * \gamma_{\text{stem}} = \mathbf{14.4 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{Gf} * A_{\text{base}} * \gamma_{\text{base}} = \mathbf{13.1 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{Gf} * A_{\text{moist}} * \gamma_{mr}' = \mathbf{48.4 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_v} = \gamma_{Gf} * A_{\text{exc}} * \gamma_b' = \mathbf{0.4 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} + F_{\text{exc}_v} = \mathbf{76.3 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A * \cos(\delta_{r,d}) * \gamma_Q * \text{Surcharge}_Q * h_{\text{eff}} = \mathbf{4.8 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G * K_A * \cos(\delta_{r,d}) * \gamma_{mr}' * h_{\text{eff}}^2 / 2 = \mathbf{18.9 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} = \mathbf{23.7 \text{ kN/m}}$$

Check stability against sliding

Base soil resistance

$$F_{\text{exc}_h} = \gamma_{Gf} * K_P * \cos(\delta_{b,d}) * \gamma_b' * (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{9.7 \text{ kN/m}}$$

Base friction

$$F_{\text{friction}} = F_{\text{total}_v} * \tan(\delta_{bb,d}) = \mathbf{35.2 \text{ kN/m}}$$

Resistance to sliding

$$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = \mathbf{44.9 \text{ kN/m}}$$

Factor of safety

$$FoS_{sl} = F_{\text{rest}} / F_{\text{total}_h} = \mathbf{1.897}$$

PASS - Resistance to sliding is greater than sliding force

Overtuning check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{Gf} * A_{\text{stem}} * \gamma_{\text{stem}} = \mathbf{14.4 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{Gf} * A_{\text{base}} * \gamma_{\text{base}} = \mathbf{13.1 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{Gf} * A_{\text{moist}} * \gamma_{mr}' = \mathbf{48.4 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_v} = \gamma_{Gf} * A_{\text{exc}} * \gamma_b' = \mathbf{0.4 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} + F_{\text{exc}_v} = \mathbf{76.3 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A * \cos(\delta_{r,d}) * \gamma_Q * \text{Surcharge}_Q * h_{\text{eff}} = \mathbf{4.8 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G * K_A * \cos(\delta_{r,d}) * \gamma_{mr}' * h_{\text{eff}}^2 / 2 = \mathbf{18.9 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_h} = -\gamma_{Gf} * K_P * \cos(\delta_{b,d}) * \gamma_b' * (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{-9.7 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{exc}_h} = \mathbf{14 \text{ kN/m}}$$

Overtuning moments on wall

Surcharge load

$$M_{\text{sur}_OT} = F_{\text{sur}_h} * x_{\text{sur}_h} = \mathbf{6.1 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}_OT} = F_{\text{moist}_h} * x_{\text{moist}_h} = \mathbf{16 \text{ kNm/m}}$$

Total

$$M_{\text{total}_OT} = M_{\text{sur}_OT} + M_{\text{moist}_OT} = \mathbf{22.2 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{\text{stem}_R} = F_{\text{stem}} * x_{\text{stem}} = \mathbf{4 \text{ kNm/m}}$$

Wall base

$$M_{\text{base}_R} = F_{\text{base}} * x_{\text{base}} = \mathbf{9.8 \text{ kNm/m}}$$

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 5				Start page no./Revision 2 17	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

Moist retained soil

$$M_{\text{moist}_R} = F_{\text{moist}_v} * x_{\text{moist}_v} = \mathbf{46 \text{ kNm/m}}$$

Base soil

$$M_{\text{exc}_R} = F_{\text{exc}_v} * x_{\text{exc}_v} - F_{\text{exc}_h} * x_{\text{exc}_h} = \mathbf{1.6 \text{ kNm/m}}$$

Total

$$M_{\text{total}_R} = M_{\text{stem}_R} + M_{\text{base}_R} + M_{\text{moist}_R} + M_{\text{exc}_R} = \mathbf{61.4 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{\text{total}_R} / M_{\text{total}_{OT}} = \mathbf{2.769}$$

PASS - Maximum restoring moment is greater than overturning moment

RETAINING WALL DESIGN

In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the UK National Annex incorporating National Amendment No.1

Tedds calculation version 2.9.11

Concrete details - Table 3.1 - Strength and deformation characteristics for concrete

Concrete strength class

C32/40

Characteristic compressive cylinder strength

$$f_{ck} = \mathbf{32 \text{ N/mm}^2}$$

Characteristic compressive cube strength

$$f_{ck,cube} = \mathbf{40 \text{ N/mm}^2}$$

Mean value of compressive cylinder strength

$$f_{cm} = f_{ck} + 8 \text{ N/mm}^2 = \mathbf{40 \text{ N/mm}^2}$$

Mean value of axial tensile strength

$$f_{ctm} = 0.3 \text{ N/mm}^2 \times (f_{ck} / 1 \text{ N/mm}^2)^{2/3} = \mathbf{3.0 \text{ N/mm}^2}$$

5% fractile of axial tensile strength

$$f_{ctk,0.05} = 0.7 \times f_{ctm} = \mathbf{2.1 \text{ N/mm}^2}$$

Secant modulus of elasticity of concrete

$$E_{cm} = 22 \text{ kN/mm}^2 \times (f_{cm} / 10 \text{ N/mm}^2)^{0.3} = \mathbf{33346 \text{ N/mm}^2}$$

Partial factor for concrete - Table 2.1N

$$\gamma_C = \mathbf{1.50}$$

Compressive strength coefficient - cl.3.1.6(1)

$$\alpha_{sc} = \mathbf{0.85}$$

Design compressive concrete strength - exp.3.15

$$f_{cd} = \alpha_{sc} \times f_{ck} / \gamma_C = \mathbf{18.1 \text{ N/mm}^2}$$

Maximum aggregate size

$$h_{agg} = \mathbf{20 \text{ mm}}$$

Ultimate strain - Table 3.1

$$\epsilon_{cu2} = \mathbf{0.0035}$$

Shortening strain - Table 3.1

$$\epsilon_{cu3} = \mathbf{0.0035}$$

Effective compression zone height factor

$$\lambda = \mathbf{0.80}$$

Effective strength factor

$$\eta = \mathbf{1.00}$$

Bending coefficient k_1

$$K_1 = \mathbf{0.40}$$

Bending coefficient k_2

$$K_2 = 1.00 * (0.6 + 0.0014 / \epsilon_{cu2}) = \mathbf{1.00}$$

Bending coefficient k_3

$$K_3 = \mathbf{0.40}$$

Bending coefficient k_4

$$K_4 = 1.00 * (0.6 + 0.0014 / \epsilon_{cu2}) = \mathbf{1.00}$$

Reinforcement details

Characteristic yield strength of reinforcement

$$f_{yk} = \mathbf{500 \text{ N/mm}^2}$$

Modulus of elasticity of reinforcement

$$E_s = \mathbf{200000 \text{ N/mm}^2}$$

Partial factor for reinforcing steel - Table 2.1N

$$\gamma_S = \mathbf{1.15}$$

Design yield strength of reinforcement

$$f_{yd} = f_{yk} / \gamma_S = \mathbf{435 \text{ N/mm}^2}$$

Cover to reinforcement

Front face of stem

$$c_{sf} = \mathbf{40 \text{ mm}}$$

Rear face of stem

$$c_{sr} = \mathbf{50 \text{ mm}}$$

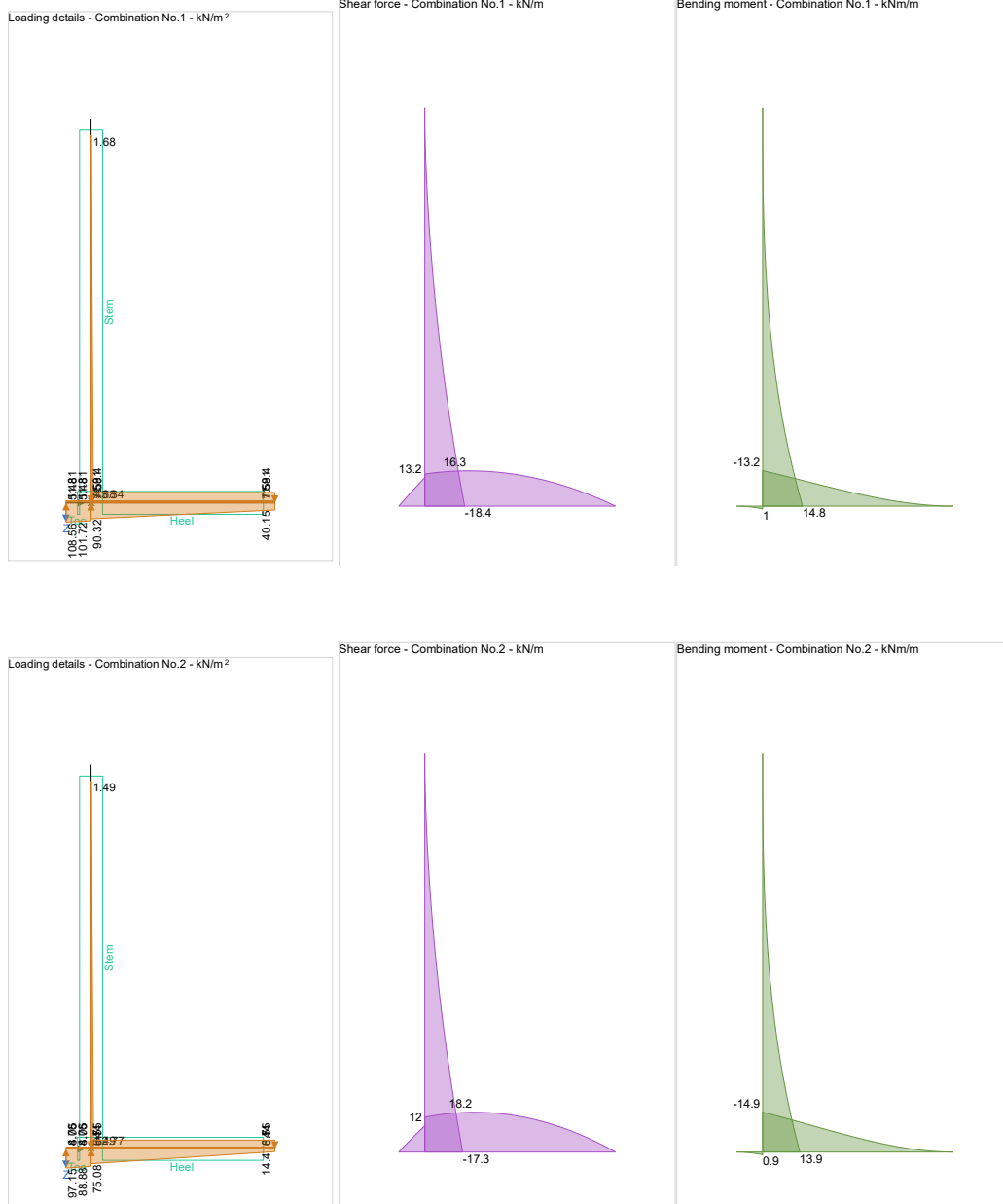
Top face of base

$$c_{bt} = \mathbf{50 \text{ mm}}$$

Bottom face of base

$$c_{bb} = \mathbf{50 \text{ mm}}$$

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 5				Start page no./Revision 2 18	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date



Check stem design at base of stem

Depth of section

h = 250 mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1

$$M = 14.8 \text{ kNm/m}$$

Depth to tension reinforcement

$$d = h - c_{sr} - \phi_{sr} / 2 = \mathbf{194 \text{ mm}}$$
$$K = M / (d^2 \times f_{ck}) = \mathbf{0.012}$$
$$K' = (2 * n * \alpha_{cc} / \gamma_C) * (1 - \lambda * (\delta - K_1) / (2 * K_2)) * (\lambda * (\delta - K_1) / (2 * K_2))$$
$$K' = 0.207$$

$K' > K$ - No compression reinforcement is required

Lever arm

$$z = \min(0.5 + 0.5 * (1 - 2 * K / (\eta * \alpha_{cc} / \gamma_c))^{0.5}, 0.95) * d = \mathbf{184 \text{ mm}}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = \mathbf{24 \text{ mm}}$$

Area of tension reinforcement required

$$A_{s,req} = M / (f_{yd} \times z) = \mathbf{185 \text{ mm}^2/m}$$

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 5				Start page no./Revision 2 19	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

Tension reinforcement provided **12 dia.bars @ 100 c/c**
Area of tension reinforcement provided $A_{sr,prov} = \pi * \phi_{sr}^2 / (4 * s_{sr}) = \mathbf{1131 \text{ mm}^2/m}$
Minimum area of reinforcement - exp.9.1N $A_{sr,min} = \max(0.26 * f_{ctm} / f_{yk}, 0.0013) * d = \mathbf{305 \text{ mm}^2/m}$
Maximum area of reinforcement - cl.9.2.1.1(3) $A_{sr,max} = 0.04 * h = \mathbf{10000 \text{ mm}^2/m}$
 $\max(A_{sr,req}, A_{sr,min}) / A_{sr,prov} = \mathbf{0.27}$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Deflection control - Section 7.4

Reference reinforcement ratio $\rho_0 = \sqrt{(f_{ck} / 1 \text{ N/mm}^2)} / 1000 = \mathbf{0.006}$
Required tension reinforcement ratio $\rho = A_{sr,req} / d = \mathbf{0.001}$
Required compression reinforcement ratio $\rho' = A_{sr,2,req} / d_2 = \mathbf{0.000}$
Structural system factor - Table 7.4N $K_b = \mathbf{0.4}$
Reinforcement factor - exp.7.17 $K_s = \min(500 \text{ N/mm}^2 / (f_{yk} * A_{sr,req} / A_{sr,prov}), 1.5) = \mathbf{1.5}$
Limiting span to depth ratio - exp.7.16.a $\min(K_s * K_b * [11 + 1.5 * \sqrt{(f_{ck} / 1 \text{ N/mm}^2)} * \rho_0 / \rho + 3.2 * \sqrt{(f_{ck} / 1 \text{ N/mm}^2)} * (\rho_0 / \rho - 1)^{3/2}], 40 * K_b) = \mathbf{16}$
Actual span to depth ratio $h_{stem} / d = \mathbf{11.9}$

PASS - Span to depth ratio is less than deflection control limit

Crack control - Section 7.3

Limiting crack width $w_{max} = \mathbf{0.4 \text{ mm}}$
Variable load factor - EN1990 – Table A1.1 $\psi_2 = \mathbf{0.6}$
Serviceability bending moment $M_{sls} = \mathbf{9.6 \text{ kNm/m}}$
Tensile stress in reinforcement $\sigma_s = M_{sls} / (A_{sr,prov} * z) = \mathbf{46.1 \text{ N/mm}^2}$
Load duration Long term
Load duration factor $K_t = \mathbf{0.4}$
Effective area of concrete in tension $A_{c,eff} = \min(2.5 * (h - d), (h - x) / 3, h / 2)$
 $A_{c,eff} = \mathbf{75250 \text{ mm}^2/m}$
Mean value of concrete tensile strength $f_{ct,eff} = f_{ctm} = \mathbf{3.0 \text{ N/mm}^2}$
Reinforcement ratio $\rho_{p,eff} = A_{sr,prov} / A_{c,eff} = \mathbf{0.015}$
Modular ratio $\alpha_E = E_s / E_{cm} = \mathbf{5.998}$
Bond property coefficient $K_1 = \mathbf{0.8}$
Strain distribution coefficient $K_2 = \mathbf{0.5}$
 $K_3 = \mathbf{3.4}$
 $K_4 = \mathbf{0.425}$
Maximum crack spacing - exp.7.11 $s_{r,max} = K_3 * C_{sr} + K_1 * K_2 * K_4 * \phi_{sr} / \rho_{p,eff} = \mathbf{306 \text{ mm}}$
Maximum crack width - exp.7.8 $w_k = s_{r,max} * \max(\sigma_s - K_t * (f_{ct,eff} / \rho_{p,eff}) * (1 + \alpha_E * \rho_{p,eff}), 0.6 * \sigma_s) / E_s$
 $w_k = \mathbf{0.042 \text{ mm}}$
 $w_k / w_{max} = \mathbf{0.106}$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force $V = \mathbf{18.4 \text{ kN/m}}$
 $C_{Rd,c} = 0.18 / \gamma_C = \mathbf{0.120}$
 $k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{2.000}$
Longitudinal reinforcement ratio $\rho_l = \min(A_{sr,prov} / d, 0.02) = \mathbf{0.006}$
 $v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} * k^{3/2} * f_{ck}^{0.5} = \mathbf{0.560 \text{ N/mm}^2}$
Design shear resistance - exp.6.2a & 6.2b $V_{Rd,c} = \max(C_{Rd,c} * k * (100 \text{ N}^2/\text{mm}^4 * \rho_l * f_{ck})^{1/3}, v_{min}) * d$
 $V_{Rd,c} = \mathbf{123.5 \text{ kN/m}}$

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 5				Start page no./Revision 2 20	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

$$V / V_{Rd,c} = 0.149$$

PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem - Section 9.6

Minimum area of reinforcement – cl.9.6.3(1) $A_{sx,req} = \max(0.25 * A_{sr,prov}, 0.001 * t_{stem}) = 283 \text{ mm}^2/\text{m}$

Maximum spacing of reinforcement – cl.9.6.3(2) $s_{sx,max} = 400 \text{ mm}$

Transverse reinforcement provided 10 dia.bars @ 200 c/c

Area of transverse reinforcement provided $A_{sx,prov} = \pi * \phi_{sx}^2 / (4 * s_{sx}) = 393 \text{ mm}^2/\text{m}$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Check base design at toe

Depth of section $h = 350 \text{ mm}$

Rectangular section in flexure - Section 6.1

Design bending moment combination 1 $M = 1 \text{ kNm/m}$

Depth to tension reinforcement $d = h - c_{bb} - \phi_{bb} / 2 = 294 \text{ mm}$

$$K = M / (d^2 * f_{ck}) = 0.000$$

$$K' = (2 * \eta * \alpha_{cc} / \gamma_c) * (1 - \lambda * (\delta - K_1) / (2 * K_2)) * (\lambda * (\delta - K_1) / (2 * K_2))$$

$$K' = 0.207$$

K' > K - No compression reinforcement is required

Lever arm $z = \min(0.5 + 0.5 * (1 - 2 * K / (\eta * \alpha_{cc} / \gamma_c))^{0.5}, 0.95) * d = 279 \text{ mm}$

Depth of neutral axis $x = 2.5 * (d - z) = 37 \text{ mm}$

Area of tension reinforcement required $A_{bb,req} = M / (f_{yd} * z) = 8 \text{ mm}^2/\text{m}$

Tension reinforcement provided 12 dia.bars @ 100 c/c

Area of tension reinforcement provided $A_{bb,prov} = \pi * \phi_{bb}^2 / (4 * s_{bb}) = 1131 \text{ mm}^2/\text{m}$

Minimum area of reinforcement - exp.9.1N $A_{bb,min} = \max(0.26 * f_{ctm} / f_{yk}, 0.0013) * d = 462 \text{ mm}^2/\text{m}$

Maximum area of reinforcement - cl.9.2.1.1(3) $A_{bb,max} = 0.04 * h = 14000 \text{ mm}^2/\text{m}$

$$\max(A_{bb,req}, A_{bb,min}) / A_{bb,prov} = 0.409$$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width $w_{max} = 0.4 \text{ mm}$

Variable load factor - EN1990 – Table A1.1 $\psi_2 = 0.6$

Serviceability bending moment $M_{sls} = 0.7 \text{ kNm/m}$

Tensile stress in reinforcement $\sigma_s = M_{sls} / (A_{bb,prov} * z) = 2.3 \text{ N/mm}^2$

Load duration Long term

Load duration factor $k_t = 0.4$

Effective area of concrete in tension $A_{c,eff} = \min(2.5 * (h - d), (h - x) / 3, h / 2)$

$$A_{c,eff} = 104417 \text{ mm}^2/\text{m}$$

Mean value of concrete tensile strength $f_{ct,eff} = f_{ctm} = 3.0 \text{ N/mm}^2$

Reinforcement ratio $\rho_{p,eff} = A_{bb,prov} / A_{c,eff} = 0.011$

Modular ratio $\alpha_e = E_s / E_{cm} = 5.998$

Bond property coefficient $k_1 = 0.8$

Strain distribution coefficient $k_2 = 0.5$

$$k_3 = 3.4$$

$$k_4 = 0.425$$

Maximum crack spacing - exp.7.11 $s_{r,max} = k_3 * c_{bb} + k_1 * k_2 * k_4 * \phi_{bb} / \rho_{p,eff} = 358 \text{ mm}$

Maximum crack width - exp.7.8 $w_k = s_{r,max} * \max(\sigma_s - k_t * (f_{ct,eff} / \rho_{p,eff}) * (1 + \alpha_e * \rho_{p,eff}), 0.6 * \sigma_s) / E_s$

$$w_k = 0.002 \text{ mm}$$

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 5				Start page no./Revision 2 21	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

$$w_k / w_{max} = \mathbf{0.006}$$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = \mathbf{13.2 \text{ kN/m}}$$

$$C_{Rd,c} = 0.18 / \gamma_c = \mathbf{0.120}$$

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{1.825}$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{bb,prov} / d, 0.02) = \mathbf{0.004}$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.488 \text{ N/mm}^2}$$

Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$$

$$V_{Rd,c} = \mathbf{148.6 \text{ kN/m}}$$

$$V / V_{Rd,c} = \mathbf{0.089}$$

PASS - Design shear resistance exceeds design shear force

Check base design at heel

Depth of section

$$h = \mathbf{350 \text{ mm}}$$

Rectangular section in flexure - Section 6.1

Design bending moment combination 2

$$M = \mathbf{14.9 \text{ kNm/m}}$$

Depth to tension reinforcement

$$d = h - c_{bt} - \phi_{bt} / 2 = \mathbf{295 \text{ mm}}$$

$$K = M / (d^2 \times f_{ck}) = \mathbf{0.005}$$

$$K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$$

$$K' = \mathbf{0.207}$$

K' > K - No compression reinforcement is required

Lever arm

$$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d = \mathbf{280 \text{ mm}}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = \mathbf{37 \text{ mm}}$$

Area of tension reinforcement required

$$A_{bt,req} = M / (f_{yd} \times z) = \mathbf{122 \text{ mm}^2/\text{m}}$$

Tension reinforcement provided

$$10 \text{ dia.bars @ } 100 \text{ c/c}$$

Area of tension reinforcement provided

$$A_{bt,prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt}) = \mathbf{785 \text{ mm}^2/\text{m}}$$

Minimum area of reinforcement - exp.9.1N

$$A_{bt,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{464 \text{ mm}^2/\text{m}}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{bt,max} = 0.04 \times h = \mathbf{14000 \text{ mm}^2/\text{m}}$$

$$\max(A_{bt,req}, A_{bt,min}) / A_{bt,prov} = \mathbf{0.591}$$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width

$$w_{max} = \mathbf{0.4 \text{ mm}}$$

Variable load factor - EN1990 – Table A1.1

$$\psi_2 = \mathbf{0.6}$$

Serviceability bending moment

$$M_{sls} = \mathbf{8.1 \text{ kNm/m}}$$

Tensile stress in reinforcement

$$\sigma_s = M_{sls} / (A_{bt,prov} \times z) = \mathbf{36.8 \text{ N/mm}^2}$$

Load duration

Long term

Load duration factor

$$k_t = \mathbf{0.4}$$

Effective area of concrete in tension

$$A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$$

$$A_{c,eff} = \mathbf{104375 \text{ mm}^2/\text{m}}$$

Mean value of concrete tensile strength

$$f_{ct,eff} = f_{ctm} = \mathbf{3.0 \text{ N/mm}^2}$$

Reinforcement ratio

$$\rho_{p,eff} = A_{bt,prov} / A_{c,eff} = \mathbf{0.008}$$

Modular ratio

$$\alpha_e = E_s / E_{cm} = \mathbf{5.998}$$

Bond property coefficient

$$k_1 = \mathbf{0.8}$$

Strain distribution coefficient

$$k_2 = \mathbf{0.5}$$

$$k_3 = \mathbf{3.4}$$

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 5				Start page no./Revision 2 22	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

Maximum crack spacing - exp.7.11

Maximum crack width - exp.7.8

$$K_4 = 0.425$$

$$s_{r,max} = k_3 * C_{bt} + k_1 * k_2 * k_4 * \phi_{bt} / \rho_{p,eff} = 396 \text{ mm}$$

$$w_k = s_{r,max} \times \max(\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_E \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$$

$$w_k = 0.044 \text{ mm}$$

$$w_k / w_{max} = 0.109$$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = 18.2 \text{ kN/m}$$

$$C_{Rd,c} = 0.18 / \gamma_c = 0.120$$

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 1.823$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{bt,prov} / d, 0.02) = 0.003$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} * k^{3/2} * f_{ck}^{0.5} = 0.487 \text{ N/mm}^2$$

Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} * k * (100 \text{ N}^2/\text{mm}^4 * \rho_l * f_{ck})^{1/3}, v_{min}) * d$$

$$V_{Rd,c} = 143.8 \text{ kN/m}$$

$$V / V_{Rd,c} = 0.127$$

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

Minimum area of reinforcement – cl.9.3.1.1(2)

$$A_{bx,req} = 0.2 * A_{bb,prov} = 226 \text{ mm}^2/\text{m}$$

Maximum spacing of reinforcement – cl.9.3.1.1(3)

$$s_{bx,max} = 450 \text{ mm}$$

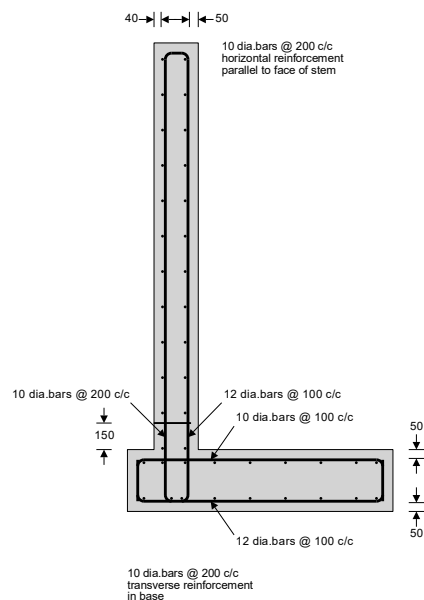
Transverse reinforcement provided

$$10 \text{ dia. bars @ } 200 \text{ c/c}$$

Area of transverse reinforcement provided

$$A_{bx,prov} = \pi * \phi_{bx}^2 / (4 * s_{bx}) = 393 \text{ mm}^2/\text{m}$$

PASS - Area of reinforcement provided is greater than area of reinforcement required



Reinforcement details



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Swansea

Project Proposed Dwellings March Hywell				Job no. C1447	
Calcs for Retaining wall Section 5				Start page no./Revision 2 23	
Calcs by TAH	Calcs date 27/11/2020	Checked by	Checked date	Approved by	Approved date

Project				Job Ref.	
Proposed Dwellings March Hywell				C1447	
Section				Sheet no./rev.	
Retaining wall Section 4				2 24	
Calc. by	Date	Chk'd by	Date	App'd by	Date
TAH	27/11/2020				

RETAINING WALL ANALYSIS

In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1

Tedds calculation version 2.9.11

Retaining wall details

Stem type;	Cantilever with stepped rear face
Stem height;	$h_{\text{stem}} = 2025 \text{ mm}$
Number of steps;	$N_{\text{steps}} = 4$
Height of step 1;	$h_{s1} = 300 \text{ mm}$
Thickness of step 1;	$t_{s1} = 1015 \text{ mm}$
Height of step 2;	$h_{s2} = 800 \text{ mm}$
Thickness of step 2;	$t_{s2} = 790 \text{ mm}$
Height of step 3;	$h_{s3} = 600 \text{ mm}$
Thickness of step 3;	$t_{s3} = 555 \text{ mm}$
Height of step 4;	$h_{s4} = 325 \text{ mm}$
Thickness of step 4;	$t_{s4} = 325 \text{ mm}$
Angle to rear face of stem;	$\alpha = 90 \text{ deg}$
Stem density;	$\gamma_{\text{stem}} = 19 \text{ kN/m}^3$
Toe length;	$l_{\text{toe}} = 125 \text{ mm}$
Heel length;	$l_{\text{heel}} = 210 \text{ mm}$
Base thickness;	$t_{\text{base}} = 350 \text{ mm}$
Base density;	$\gamma_{\text{base}} = 25 \text{ kN/m}^3$
Height of retained soil;	$h_{\text{ret}} = 1775 \text{ mm}$
Angle of soil surface;	$\beta = 0 \text{ deg}$
Depth of cover;	$d_{\text{cover}} = 250 \text{ mm}$

Retained soil properties

Soil type;	Medium dense well graded sand and gravel
Moist density;	$\gamma_{\text{mr}} = 19 \text{ kN/m}^3$
Saturated density;	$\gamma_{\text{sr}} = 21 \text{ kN/m}^3$
Characteristic effective shear resistance angle;	$\phi'_{r,k} = 36 \text{ deg}$
Characteristic wall friction angle;	$\delta_{r,k} = 18 \text{ deg}$

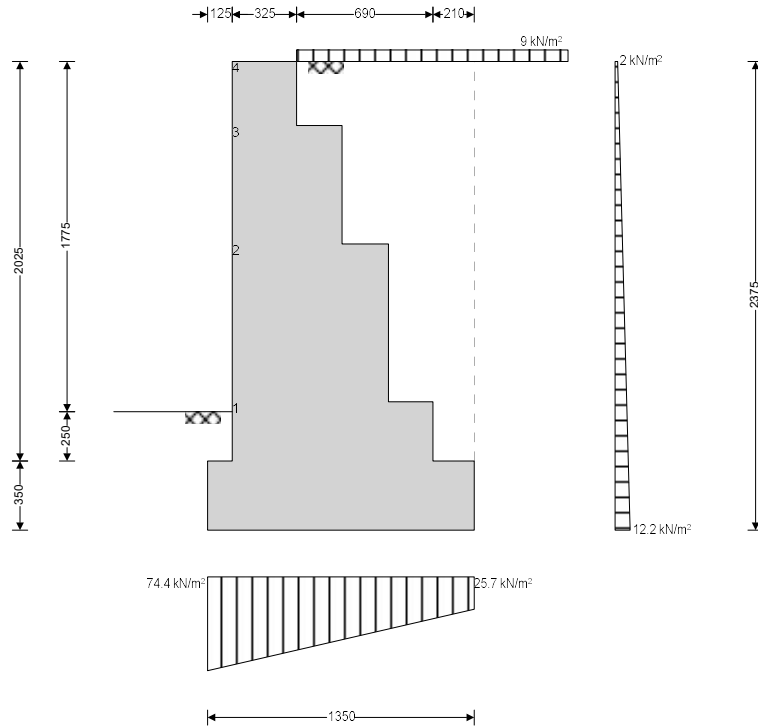
Base soil properties

Soil type;	Medium dense rock fill
Soil density;	$\gamma_b = 16.3 \text{ kN/m}^3$
Characteristic effective shear resistance angle;	$\phi'_{b,k} = 36 \text{ deg}$
Characteristic wall friction angle;	$\delta_{b,k} = 18 \text{ deg}$
Characteristic base friction angle;	$\delta_{bb,k} = 30 \text{ deg}$
Presumed bearing capacity;	$P_{\text{bearing}} = 170 \text{ kN/m}^2$

Loading details

Variable surcharge load;	Surcharge _Q = 9 kN/m ²
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Project				Job Ref.	
Proposed Dwellings March Hywell				C1447	
Section				Sheet no./rev.	
Retaining wall Section 4				2 25	
Calc. by	Date	Chk'd by	Date	App'd by	Date
TAH	27/11/2020				



General arrangement

Calculate retaining wall geometry

Base length;

Moist soil height;

Length of surcharge load;

- Distance to vertical component;

Effective height of wall;

- Distance to horizontal component;

Area of wall stem;

- Distance to vertical component;

Area of wall base;

- Distance to vertical component;

Area of moist soil;

- Distance to vertical component;

- Distance to horizontal component;

Area of base soil;

- Distance to vertical component;

- Distance to horizontal component;

Area of excavated base soil;

$$l_{base} = l_{toe} + t_{s1} + l_{heel} = \mathbf{1350 \text{ mm}}$$

$$h_{moist} = h_{soil} = \mathbf{2025 \text{ mm}}$$

$$l_{sur} = (l_{heel} + t_{s1} - t_{s4}) = \mathbf{900 \text{ mm}}$$

$$x_{sur_v} = l_{base} - (l_{heel} + t_{s1} - t_{s4}) / 2 = \mathbf{900 \text{ mm}}$$

$$h_{eff} = h_{base} + d_{cover} + h_{ret} = \mathbf{2375 \text{ mm}}$$

$$x_{sur_h} = h_{eff} / 2 = \mathbf{1188 \text{ mm}}$$

$$A_{stem} = h_{s1} * t_{s1} + h_{s2} * t_{s2} + h_{s3} * t_{s3} + h_{s4} * t_{s4} = \mathbf{1.375 \text{ m}^2}$$

$$x_{stem} = l_{base} - (h_{s1} * t_{s1} * (l_{heel} + t_{s1} - t_{s1} / 2) + h_{s2} * t_{s2} * (l_{heel} + t_{s1} - t_{s2} / 2) + h_{s3} * t_{s3} * (l_{heel} + t_{s1} - t_{s3} / 2) + h_{s4} * t_{s4} * (l_{heel} + t_{s1} - t_{s4} / 2)) / A_{stem} = \mathbf{499 \text{ mm}}$$

$$A_{base} = l_{base} * t_{base} = \mathbf{0.473 \text{ m}^2}$$

$$x_{base} = l_{base} / 2 = \mathbf{675 \text{ mm}}$$

$$A_{moist} = l_{heel} * h_{s1} + (l_{heel} + t_{s1} - t_{s2}) * h_{s2} + (l_{heel} + t_{s1} - t_{s3}) * h_{s3} + (l_{heel} + t_{s1} - t_{s4}) * h_{s4} = \mathbf{1.106 \text{ m}^2}$$

$$x_{moist_v} = l_{base} - (l_{heel} * h_{s1} * l_{heel} / 2 + (l_{heel} + t_{s1} - t_{s2}) * h_{s2} * (l_{heel} + t_{s1} - t_{s2}) / 2 + (l_{heel} + t_{s1} - t_{s3}) * h_{s3} * (l_{heel} + t_{s1} - t_{s3}) / 2 + (l_{heel} + t_{s1} - t_{s4}) * h_{s4} * (l_{heel} + t_{s1} - t_{s4}) / 2) / A_{moist} = \mathbf{1035 \text{ mm}}$$

$$x_{moist_h} = h_{eff} / 3 = \mathbf{792 \text{ mm}}$$

$$A_{pass} = d_{cover} * l_{toe} = \mathbf{0.031 \text{ m}^2}$$

$$x_{pass_v} = l_{base} - (d_{cover} * l_{toe} * (l_{base} - l_{toe} / 2)) / A_{pass} = \mathbf{63 \text{ mm}}$$

$$x_{pass_h} = (d_{cover} + h_{base}) / 3 = \mathbf{200 \text{ mm}}$$

$$A_{exc} = h_{pass} * l_{toe} = \mathbf{0.031 \text{ m}^2}$$

Project				Job Ref.	
Proposed Dwellings March Hywell				C1447	
Section				Sheet no./rev.	
Retaining wall Section 4				2 26	
Calc. by	Date	Chk'd by	Date	App'd by	Date
TAH	27/11/2020				

- Distance to vertical component;
- Distance to horizontal component;

$$X_{exc_v} = l_{base} - (h_{pass} * l_{toe} * (l_{base} - l_{toe} / 2)) / A_{exc} = \mathbf{63 \text{ mm}}$$

$$X_{exc_h} = (h_{pass} + h_{base}) / 3 = \mathbf{200 \text{ mm}}$$

Using Coulomb theory

Active pressure coefficient;

$$K_A = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 * \sin(\alpha - \delta_{r,k}) * [1 + \sqrt{(\sin(\phi'_{r,k} + \delta_{r,k}) * \sin(\phi'_{r,k} - \beta) / (\sin(\alpha - \delta_{r,k}) * \sin(\alpha + \beta))}]^2) = \mathbf{0.236}$$

Passive pressure coefficient;

$$K_P = \sin(90 - \phi'_{b,k})^2 / (\sin(90 + \delta_{b,k}) * [1 - \sqrt{(\sin(\phi'_{b,k} + \delta_{b,k}) * \sin(\phi'_{b,k} - \beta) / (\sin(90 + \delta_{b,k}))}]^2) = \mathbf{8.022}$$

Bearing pressure check

Vertical forces on wall

Wall stem;

$$F_{stem} = A_{stem} * \gamma_{stem} = \mathbf{26.1 \text{ kN/m}}$$

Wall base;

$$F_{base} = A_{base} * \gamma_{base} = \mathbf{11.8 \text{ kN/m}}$$

Surcharge load;

$$F_{sur_v} = \text{Surcharge}_Q * (l_{heel} + t_{s1} - t_{s4}) = \mathbf{8.1 \text{ kN/m}}$$

Moist retained soil;

$$F_{moist_v} = A_{moist} * \gamma_{mr} = \mathbf{21 \text{ kN/m}}$$

Base soil;

$$F_{pass_v} = A_{pass} * \gamma_b = \mathbf{0.5 \text{ kN/m}}$$

Total;

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} + F_{pass_v} = \mathbf{67.6 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load;

$$F_{sur_h} = K_A * \cos(\delta_{r,k}) * \text{Surcharge}_Q * h_{eff} = \mathbf{4.8 \text{ kN/m}}$$

Moist retained soil;

$$F_{moist_h} = K_A * \cos(\delta_{r,k}) * \gamma_{mr} * h_{eff}^2 / 2 = \mathbf{12 \text{ kN/m}}$$

Base soil;

$$F_{pass_h} = \max(-K_P * \cos(\delta_{b,k}) * \gamma_b * (d_{cover} + h_{base})^2 / 2, -(F_{moist_h} + F_{sur_h})) = \mathbf{-16.8 \text{ kN/m}}$$

Total;

$$F_{total_h} = \max(F_{sur_h} + F_{moist_h} + F_{pass_h} - F_{total_v} * \tan(\delta_{bb,k}), 0 \text{ kN/m}) = \mathbf{0 \text{ kN/m}}$$

Moments on wall

Wall stem;

$$M_{stem} = F_{stem} * X_{stem} = \mathbf{13 \text{ kNm/m}}$$

Wall base;

$$M_{base} = F_{base} * X_{base} = \mathbf{8 \text{ kNm/m}}$$

Surcharge load;

$$M_{sur} = F_{sur_v} * X_{sur_v} - F_{sur_h} * X_{sur_h} = \mathbf{1.6 \text{ kNm/m}}$$

Moist retained soil;

$$M_{moist} = F_{moist_v} * X_{moist_v} - F_{moist_h} * X_{moist_h} = \mathbf{12.2 \text{ kNm/m}}$$

Base soil;

$$M_{pass} = F_{pass_v} * X_{pass_v} - F_{pass_h} * X_{pass_h} = \mathbf{3.4 \text{ kNm/m}}$$

Total;

$$M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} = \mathbf{38.2 \text{ kNm/m}}$$

Check bearing pressure

Distance to reaction;

$$\bar{x} = M_{total} / F_{total_v} = \mathbf{565 \text{ mm}}$$

Eccentricity of reaction;

$$e = \bar{x} - l_{base} / 2 = \mathbf{-110 \text{ mm}}$$

Loaded length of base;

$$l_{load} = l_{base} = \mathbf{1350 \text{ mm}}$$

Bearing pressure at toe;

$$q_{toe} = F_{total_v} / l_{base} * (1 - 6 * e / l_{base}) = \mathbf{74.4 \text{ kN/m}^2}$$

Bearing pressure at heel;

$$q_{heel} = F_{total_v} / l_{base} * (1 + 6 * e / l_{base}) = \mathbf{25.7 \text{ kN/m}^2}$$

Factor of safety;

$$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = \mathbf{2.285}$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

Partial factors on actions - Table A.3 - Combination 1

Partial factor set;

$$A1$$

Permanent unfavourable action;

$$\gamma_G = \mathbf{1.35}$$

Permanent favourable action;

$$\gamma_{Gf} = \mathbf{1.00}$$

Variable unfavourable action;

$$\gamma_Q = \mathbf{1.50}$$

Variable favourable action;

$$\gamma_{Qf} = \mathbf{0.00}$$

Partial factors for soil parameters – Table A.4 - Combination 1

Project				Job Ref.	
Proposed Dwellings March Hywell				C1447	
Section				Sheet no./rev.	
Retaining wall Section 4				2 27	
Calc. by	Date	Chk'd by	Date	App'd by	Date
TAH	27/11/2020				

Soil parameter set; M1
Angle of shearing resistance; $\gamma_{\phi'} = 1.00$
Effective cohesion; $\gamma_{c'} = 1.00$
Weight density; $\gamma_{\gamma} = 1.00$

Library item; Partial factors output

Retained soil properties

Design moist density; $\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma} = 19 \text{ kN/m}^3$
Design saturated density; $\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma} = 21 \text{ kN/m}^3$
Design effective shear resistance angle; $\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 36 \text{ deg}$
Design wall friction angle; $\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = 18 \text{ deg}$

Base soil properties

Design soil density; $\gamma_b' = \gamma_b / \gamma_{\gamma} = 16.3 \text{ kN/m}^3$
Design effective shear resistance angle; $\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = 36 \text{ deg}$
Design wall friction angle; $\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = 18 \text{ deg}$
Design base friction angle; $\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 30 \text{ deg}$
Design effective cohesion; $c'_{b,d} = c'_{b,k} / \gamma_{c'} = 0 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient; $K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 * \sin(\alpha - \delta_{r,d}) * [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) * \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) * \sin(\alpha + \beta))]}]^2) = 0.236$
Passive pressure coefficient; $K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) * [1 - \sqrt{[\sin(\phi'_{b,d} + \delta_{b,d}) * \sin(\phi'_{b,d} - \beta) / (\sin(90 + \delta_{b,d}))]}]^2) = 8.022$

Sliding check

Vertical forces on wall

Wall stem; $F_{stem} = \gamma_{Gf} * A_{stem} * \gamma_{stem} = 26.1 \text{ kN/m}$
Wall base; $F_{base} = \gamma_{Gf} * A_{base} * \gamma_{base} = 11.8 \text{ kN/m}$
Moist retained soil; $F_{moist_v} = \gamma_{Gf} * A_{moist} * \gamma_{mr}' = 21 \text{ kN/m}$
Base soil; $F_{exc_v} = \gamma_{Gf} * A_{exc} * \gamma_b' = 0.5 \text{ kN/m}$
Total; $F_{total_v} = F_{stem} + F_{base} + F_{moist_v} + F_{exc_v} = 59.5 \text{ kN/m}$

Horizontal forces on wall

Surcharge load; $F_{sur_h} = K_A * \cos(\delta_{r,d}) * \gamma_Q * \text{Surcharge}_Q * h_{eff} = 7.2 \text{ kN/m}$
Moist retained soil; $F_{moist_h} = \gamma_G * K_A * \cos(\delta_{r,d}) * \gamma_{mr}' * h_{eff}^2 / 2 = 16.2 \text{ kN/m}$
Total; $F_{total_h} = F_{sur_h} + F_{moist_h} = 23.4 \text{ kN/m}$

Check stability against sliding

Base soil resistance; $F_{exc_h} = \gamma_{Gf} * K_P * \cos(\delta_{b,d}) * \gamma_b' * (h_{pass} + h_{base})^2 / 2 = 22.3 \text{ kN/m}$
Base friction; $F_{friction} = F_{total_v} * \tan(\delta_{bb,d}) = 34.3 \text{ kN/m}$
Resistance to sliding; $F_{rest} = F_{exc_h} + F_{friction} = 56.6 \text{ kN/m}$
Factor of safety; $FoS_{sl} = F_{rest} / F_{total_h} = 2.416$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem; $F_{stem} = \gamma_{Gf} * A_{stem} * \gamma_{stem} = 26.1 \text{ kN/m}$
Wall base; $F_{base} = \gamma_{Gf} * A_{base} * \gamma_{base} = 11.8 \text{ kN/m}$
Moist retained soil; $F_{moist_v} = \gamma_{Gf} * A_{moist} * \gamma_{mr}' = 21 \text{ kN/m}$
Base soil; $F_{exc_v} = \gamma_{Gf} * A_{exc} * \gamma_b' = 0.5 \text{ kN/m}$

Project				Job Ref.	
Proposed Dwellings March Hywell				C1447	
Section				Sheet no./rev.	
Retaining wall Section 4				2 28	
Calc. by	Date	Chk'd by	Date	App'd by	Date
TAH	27/11/2020				

Total;

$$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} + F_{exc_v} = 59.5 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load;

$$F_{sur_h} = K_A * \cos(\delta_{r,d}) * \gamma_Q * \text{Surcharge}_Q * h_{eff} = 7.2 \text{ kN/m}$$

Moist retained soil;

$$F_{moist_h} = \gamma_G * K_A * \cos(\delta_{r,d}) * \gamma_{mr}' * h_{eff}^2 / 2 = 16.2 \text{ kN/m}$$

Base soil;

$$F_{exc_h} = -\gamma_{Gf} * K_P * \cos(\delta_{b,d}) * \gamma_b' * (h_{pass} + h_{base})^2 / 2 = -22.3 \text{ kN/m}$$

Total;

$$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = 1.1 \text{ kN/m}$$

Overtuning moments on wall

Surcharge load;

$$M_{sur_OT} = F_{sur_h} * x_{sur_h} = 8.6 \text{ kNm/m}$$

Moist retained soil;

$$M_{moist_OT} = F_{moist_h} * x_{moist_h} = 12.9 \text{ kNm/m}$$

Total;

$$M_{total_OT} = M_{sur_OT} + M_{moist_OT} = 21.4 \text{ kNm/m}$$

Restoring moments on wall

Wall stem;

$$M_{stem_R} = F_{stem} * x_{stem} = 13 \text{ kNm/m}$$

Wall base;

$$M_{base_R} = F_{base} * x_{base} = 8 \text{ kNm/m}$$

Moist retained soil;

$$M_{moist_R} = F_{moist_v} * x_{moist_v} = 21.7 \text{ kNm/m}$$

Base soil;

$$M_{exc_R} = F_{exc_v} * x_{exc_v} - F_{exc_h} * x_{exc_h} = 4.5 \text{ kNm/m}$$

Total;

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} + M_{exc_R} = 47.2 \text{ kNm/m}$$

Check stability against overturning

Factor of safety;

$$Fo_{Sot} = M_{total_R} / M_{total_OT} = 2.206$$

PASS - Maximum restoring moment is greater than overturning moment

Design approach 1

Partial factors on actions - Table A.3 - Combination 2

Partial factor set;

A2

Permanent unfavourable action;

$$\gamma_G = 1.00$$

Permanent favourable action;

$$\gamma_{Gf} = 1.00$$

Variable unfavourable action;

$$\gamma_Q = 1.30$$

Variable favourable action;

$$\gamma_{Qf} = 0.00$$

Partial factors for soil parameters – Table A.4 - Combination 2

Soil parameter set;

M2

Angle of shearing resistance;

$$\gamma_{\phi'} = 1.25$$

Effective cohesion;

$$\gamma_{c'} = 1.25$$

Weight density;

$$\gamma_{\gamma} = 1.00$$

Library item; Partial factors output

Retained soil properties

Design moist density;

$$\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma} = 19 \text{ kN/m}^3$$

Design saturated density;

$$\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma} = 21 \text{ kN/m}^3$$

Design effective shear resistance angle;

$$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 30.2 \text{ deg}$$

Design wall friction angle;

$$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = 14.6 \text{ deg}$$

Base soil properties

Design soil density;

$$\gamma_b' = \gamma_b / \gamma_{\gamma} = 16.3 \text{ kN/m}^3$$

Design effective shear resistance angle;

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = 30.2 \text{ deg}$$

Design wall friction angle;

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = 14.6 \text{ deg}$$

Design base friction angle;

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 24.8 \text{ deg}$$

Design effective cohesion;

$$c'_{b,d} = c'_{b,k} / \gamma_{c'} = 0 \text{ kN/m}^2$$

Project Proposed Dwellings March Hywell		Job Ref.	
		C1447	
Section		Sheet no./rev.	
Retaining wall Section 4		2 29	
Calc. by	Date	Chk'd by	Date
TAH	27/11/2020		
		App'd by	Date

Using Coulomb theory

Active pressure coefficient;

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \sin(\alpha - \delta_{r,d}) * [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) * \sin(\phi'_{r,d} - \beta)] / (\sin(\alpha - \delta_{r,d}) * \sin(\alpha + \beta))}]^2) = \mathbf{0.300}$$

Passive pressure coefficient;

$$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) * [1 - \sqrt{[\sin(\phi'_{b,d} + \delta_{b,d}) * \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))}]^2) = \mathbf{4.938}$$

Sliding check

Vertical forces on wall

Wall stem;

$$F_{stem} = \gamma_{Gf} * A_{stem} * \gamma_{stem} = \mathbf{26.1 \text{ kN/m}}$$

Wall base;

$$F_{base} = \gamma_{Gf} * A_{base} * \gamma_{base} = \mathbf{11.8 \text{ kN/m}}$$

Moist retained soil;

$$F_{moist_v} = \gamma_{Gf} * A_{moist} * \gamma_{mr}' = \mathbf{21 \text{ kN/m}}$$

Base soil;

$$F_{exc_v} = \gamma_{Gf} * A_{exc} * \gamma_b' = \mathbf{0.5 \text{ kN/m}}$$

Total;

$$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} + F_{exc_v} = \mathbf{59.5 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load;

$$F_{sur_h} = K_A * \cos(\delta_{r,d}) * \gamma_Q * \text{Surcharge}_Q * h_{eff} = \mathbf{8.1 \text{ kN/m}}$$

Moist retained soil;

$$F_{moist_h} = \gamma_G * K_A * \cos(\delta_{r,d}) * \gamma_{mr}' * h_{eff}^2 / 2 = \mathbf{15.6 \text{ kN/m}}$$

Total;

$$F_{total_h} = F_{sur_h} + F_{moist_h} = \mathbf{23.6 \text{ kN/m}}$$

Check stability against sliding

Base soil resistance;

$$F_{exc_h} = \gamma_{Gf} * K_P * \cos(\delta_{b,d}) * \gamma_b' * (h_{pass} + h_{base})^2 / 2 = \mathbf{14 \text{ kN/m}}$$

Base friction;

$$F_{friction} = F_{total_v} * \tan(\delta_{bb,d}) = \mathbf{27.5 \text{ kN/m}}$$

Resistance to sliding;

$$F_{rest} = F_{exc_h} + F_{friction} = \mathbf{41.4 \text{ kN/m}}$$

Factor of safety;

$$FoS_{sl} = F_{rest} / F_{total_h} = \mathbf{1.754}$$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem;

$$F_{stem} = \gamma_{Gf} * A_{stem} * \gamma_{stem} = \mathbf{26.1 \text{ kN/m}}$$

Wall base;

$$F_{base} = \gamma_{Gf} * A_{base} * \gamma_{base} = \mathbf{11.8 \text{ kN/m}}$$

Moist retained soil;

$$F_{moist_v} = \gamma_{Gf} * A_{moist} * \gamma_{mr}' = \mathbf{21 \text{ kN/m}}$$

Base soil;

$$F_{exc_v} = \gamma_{Gf} * A_{exc} * \gamma_b' = \mathbf{0.5 \text{ kN/m}}$$

Total;

$$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} + F_{exc_v} = \mathbf{59.5 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load;

$$F_{sur_h} = K_A * \cos(\delta_{r,d}) * \gamma_Q * \text{Surcharge}_Q * h_{eff} = \mathbf{8.1 \text{ kN/m}}$$

Moist retained soil;

$$F_{moist_h} = \gamma_G * K_A * \cos(\delta_{r,d}) * \gamma_{mr}' * h_{eff}^2 / 2 = \mathbf{15.6 \text{ kN/m}}$$

Base soil;

$$F_{exc_h} = -\gamma_{Gf} * K_P * \cos(\delta_{b,d}) * \gamma_b' * (h_{pass} + h_{base})^2 / 2 = \mathbf{-14 \text{ kN/m}}$$

Total;

$$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = \mathbf{9.6 \text{ kN/m}}$$

Overturning moments on wall

Surcharge load;

$$M_{sur_OT} = F_{sur_h} * x_{sur_h} = \mathbf{9.6 \text{ kNm/m}}$$

Moist retained soil;

$$M_{moist_OT} = F_{moist_h} * x_{moist_h} = \mathbf{12.3 \text{ kNm/m}}$$

Total;

$$M_{total_OT} = M_{sur_OT} + M_{moist_OT} = \mathbf{21.9 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem;

$$M_{stem_R} = F_{stem} * x_{stem} = \mathbf{13 \text{ kNm/m}}$$

Wall base;

$$M_{base_R} = F_{base} * x_{base} = \mathbf{8 \text{ kNm/m}}$$

Moist retained soil;

$$M_{moist_R} = F_{moist_v} * x_{moist_v} = \mathbf{21.7 \text{ kNm/m}}$$

Base soil;

$$M_{exc_R} = F_{exc_v} * x_{exc_v} - F_{exc_h} * x_{exc_h} = \mathbf{2.8 \text{ kNm/m}}$$

Total;

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} + M_{exc_R} = \mathbf{45.6 \text{ kNm/m}}$$

		Project		Job Ref.	
		Proposed Dwellings March Hywell		C1447	
		Section		Sheet no./rev.	
		Retaining wall Section 4		2 30	
Calc. by	Date	Chk'd by	Date	App'd by	Date
TAH	27/11/2020				

Check stability against overturning

Factor of safety;

$$FoS_{ot} = M_{total_R} / M_{total_OT} = 2.081$$

PASS - Maximum restoring moment is greater than overturning moment

RETAINING WALL DESIGN

In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the UK National Annex incorporating National Amendment No.1 and EN1996-1-1:2005 incorporating Corrigenda dated February 2006 and July 2009 and the UK National Annex

Tedds calculation version 2.9.11

Concrete details - Table 3.1 - Strength and deformation characteristics for concrete

Concrete strength class;	C32/40
Characteristic compressive cylinder strength;	$f_{ck} = 32 \text{ N/mm}^2$
Characteristic compressive cube strength;	$f_{ck,cube} = 40 \text{ N/mm}^2$
Mean value of compressive cylinder strength;	$f_{cm} = f_{ck} + 8 \text{ N/mm}^2 = 40 \text{ N/mm}^2$
Mean value of axial tensile strength;	$f_{ctm} = 0.3 \text{ N/mm}^2 \times (f_{ck} / 1 \text{ N/mm}^2)^{2/3} = 3.0 \text{ N/mm}^2$
5% fractile of axial tensile strength;	$f_{ctk,0.05} = 0.7 \times f_{ctm} = 2.1 \text{ N/mm}^2$
Secant modulus of elasticity of concrete;	$E_{cm} = 22 \text{ kN/mm}^2 \times (f_{cm} / 10 \text{ N/mm}^2)^{0.3} = 33346 \text{ N/mm}^2$
Partial factor for concrete - Table 2.1N;	$\gamma_C = 1.50$
Compressive strength coefficient - cl.3.1.6(1);	$\alpha_{cc} = 0.85$
Design compressive concrete strength - exp.3.15;	$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C = 18.1 \text{ N/mm}^2$
Maximum aggregate size;	$h_{agg} = 20 \text{ mm}$
Ultimate strain - Table 3.1;	$\epsilon_{cu2} = 0.0035$
Shortening strain - Table 3.1;	$\epsilon_{cu3} = 0.0035$
Effective compression zone height factor;	$\lambda = 0.80$
Effective strength factor;	$\eta = 1.00$
Bending coefficient k_1 ;	$K_1 = 0.40$
Bending coefficient k_2 ;	$K_2 = 1.00 * (0.6 + 0.0014/\epsilon_{cu2}) = 1.00$
Bending coefficient k_3 ;	$K_3 = 0.40$
Bending coefficient k_4 ;	$K_4 = 1.00 * (0.6 + 0.0014/\epsilon_{cu2}) = 1.00$

Reinforcement details

Characteristic yield strength of reinforcement;	$f_{yk} = 500 \text{ N/mm}^2$
Modulus of elasticity of reinforcement;	$E_s = 200000 \text{ N/mm}^2$
Partial factor for reinforcing steel - Table 2.1N;	$\gamma_S = 1.15$
Design yield strength of reinforcement;	$f_{yd} = f_{yk} / \gamma_S = 435 \text{ N/mm}^2$

Cover to reinforcement

Top face of base;	$c_{bt} = 50 \text{ mm}$
Bottom face of base;	$c_{bb} = 50 \text{ mm}$

Masonry details - Section 3.1

Masonry type;	Aggregate concrete - Group 1
Normalised mean compressive strength;	$f_b = 10.4 \text{ N/mm}^2$
Characteristic flexural strength - cl.6.3.4(1);	$f_{xk} = 0 \text{ N/mm}^2$
Initial shear strength - Table NA.5;	$f_{vko} = 0.15 \text{ N/mm}^2$

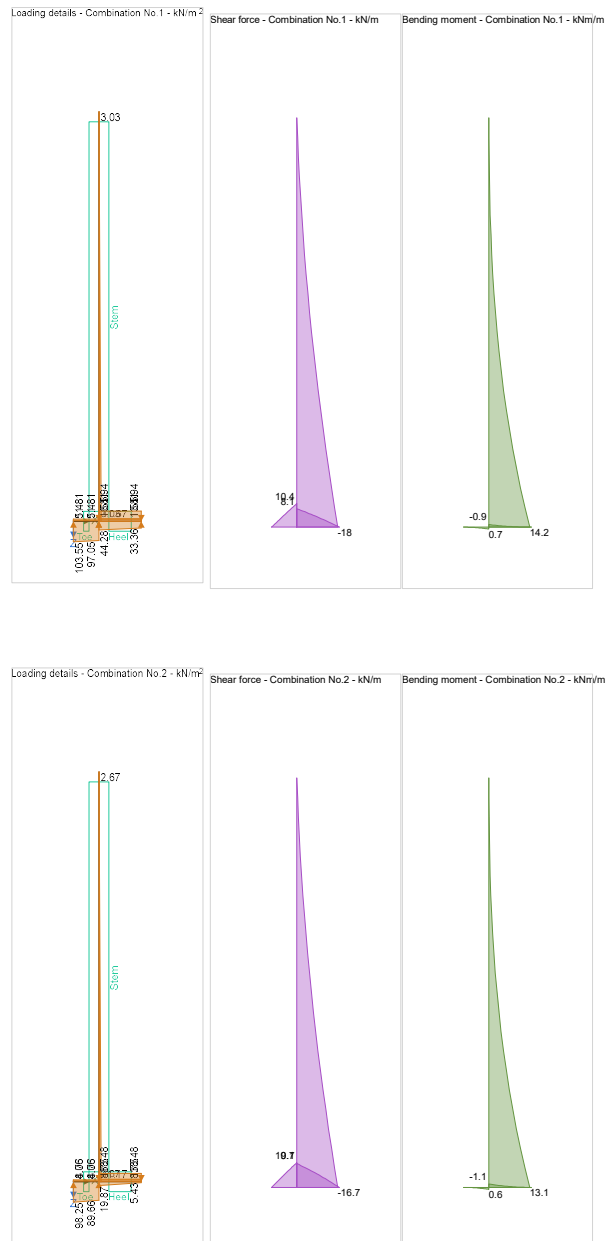
Mortar details - Section 3.2

Mortar type;	General purpose - M4, prescribed mix
Compressive strength of mortar;	$f_m = 4 \text{ N/mm}^2$

Project				Job Ref.	
Proposed Dwellings March Hywell				C1447	
Section				Sheet no./rev.	
Retaining wall Section 4				2 31	
Calc. by	Date	Chk'd by	Date	App'd by	Date
TAH	27/11/2020				

Ultimate limit states - Table NA.1

Class of execution control;	1
Category of manufacture control;	1
Partial factor for direct or flexural compression;	$\gamma_{Mc} = 2.3$
Partial factor for flexural tension;	$\gamma_{Mt} = 2.3$
Partial factor for shear;	$\gamma_{Mv} = 2.5$



Check stem design at base of stem

Depth of section; $t = 1015 \text{ mm}$

Masonry characteristics

Compressive strength constants - Table NA.4	$K = 0.550$
Characteristic compressive strength - cl.3.6.1.2(1)	$f_k = K * f_b^{0.7} * f_m^{0.3} = 4.294 \text{ N/mm}^2$
Design compressive strength	$f_d = f_k / \gamma_{Mc} = 1.867 \text{ N/mm}^2$

Project Proposed Dwellings March Hywell		Job Ref.	
		C1447	
Section		Sheet no./rev.	
Retaining wall Section 4		2 32	
Calc. by	Date	Chk'd by	Date
TAH	27/11/2020		
App'd by	Date		

Design flexural strength	$f_{xd} = f_{xk} / \gamma_{Mt} = \mathbf{0.083 \text{ N/mm}^2}$
Height of masonry	$h_{wt} = h_{stem} = \mathbf{2025 \text{ mm}}$
Compressive axial force combination 0	$F_x = \gamma_{Gf} * \gamma_{stem} * (h_{s1} * t_{s1} + h_{s2} * t_{s2} + h_{s3} * t_{s3} + h_{s4} * t_{s4}) = \mathbf{26.1 \text{ kN/m}}$
Moment combination 0	$M_x = \gamma_{Gf} * \gamma_{stem} * (h_{s1} * t_{s1} * t_{s1} / 2 + h_{s2} * t_{s2} * t_{s2} / 2 + h_{s3} * t_{s3} * t_{s3} / 2 + h_{s4} * t_{s4} * t_{s4} / 2) = \mathbf{9.8 \text{ kNm/m}}$
Eccentricity of axial load	$e = \max(\text{abs}(t / 2 - M_x / F_x), 0.05 \times t) = \mathbf{133.9 \text{ mm}}$
Capacity reduction factor - exp.6.4	$\Phi = 1 - 2 \times e / t = \mathbf{0.736}$
Design vertical resistance - exp.6.2	$N_{Rd} = \Phi \times t \times f_d = \mathbf{1395.1 \text{ kN/m}}$
Design vertical compressive stress	$\sigma_d = \min(F_x / t, 0.15 \times N_{Rd} / t) = \mathbf{0.026 \text{ N/mm}^2}$
Apparent design flexural strength - exp.6.16	$f_{xd,app} = f_{xd} + \sigma_d = \mathbf{0.109 \text{ N/mm}^2}$
Limit of charact. shear strength - exp. 3.1;	$f_{vk,lim} = 0.065 * f_b = \mathbf{0.676 \text{ N/mm}^2}$
Characteristic shear strength - exp.3.5	$f_{vk} = \min(f_{vko} + 0.4 \times \sigma_d, f_{vk,lim}) = \mathbf{0.16 \text{ N/mm}^2}$
Design shear strength	$f_{vd} = f_{vk} / \gamma_{Mv} = \mathbf{0.064 \text{ N/mm}^2}$

Library item: Masonry characteristics output

Unreinforced masonry walls subjected to lateral loading - Section 6.3

Design bending moment combination 1;	$M = \mathbf{14.189 \text{ kNm/m}}$
Elastic section modulus of wall;	$Z = t^2 / 6 = \mathbf{171704167 \text{ mm}^3/\text{m}}$
Moment of resistance of masonry - exp.6.15;	$M_{Rd} = f_{xd,app} \times Z = \mathbf{18.3 \text{ kNm/m}}$

PASS - Moment of resistance is more than applied design moment

Unreinforced masonry walls subjected to shear loading - Section 6.2

Design shear force	$V = \mathbf{17.951 \text{ kN/m}}$
Maximum compressive stress;	$\sigma_{max} = F_x / t + M / Z = \mathbf{0.108 \text{ N/mm}^2}$
Minimum compressive stress;	$\sigma_{min} = F_x / t - M / Z = \mathbf{-0.057 \text{ N/mm}^2}$
Thickness of wall in compression;	$t_c = t * \sigma_{max} / (\sigma_{max} - \sigma_{min}) = \mathbf{666 \text{ mm}}$
Design shear resistance - exp.6.13;	$V_{Rd} = f_{vd} \times t_c = \mathbf{42.676 \text{ kN/m}}$
	$V / V_{Rd} = \mathbf{0.421}$

PASS - Design shear resistance exceeds applied design shear force

Check stem design at 300 mm

Depth of section;	$t = \mathbf{790 \text{ mm}}$
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Masonry characteristics

Compressive strength constants - Table NA.4	$K = 0.550$
Characteristic compressive strength - cl.3.6.1.2(1)	$f_k = K * f_b^{0.7} * f_m^{0.3} = \mathbf{4.294 \text{ N/mm}^2}$
Design compressive strength	$f_d = f_k / \gamma_{Mc} = \mathbf{1.867 \text{ N/mm}^2}$
Design flexural strength	$f_{xd} = f_{xk} / \gamma_{Mt} = 0.083 \text{ N/mm}^2$
Height of masonry	$h_{wt} = h_{stem} - 300 \text{ mm} = \mathbf{1725 \text{ mm}}$
Compressive axial force combination 0	$F_x = \gamma_{Gf} * \gamma_{stem} * (h_{s2} * t_{s2} + h_{s3} * t_{s3} + h_{s4} * t_{s4}) = \mathbf{20.3 \text{ kN/m}}$
Moment combination 0	$M_x = \gamma_{Gf} * \gamma_{stem} * (h_{s2} * t_{s2} * t_{s2} / 2 + h_{s3} * t_{s3} * t_{s3} / 2 + h_{s4} * t_{s4} * t_{s4} / 2) = \mathbf{6.8 \text{ kNm/m}}$
Eccentricity of axial load	$e = \max(\text{abs}(t / 2 - M_x / F_x), 0.05 \times t) = \mathbf{59.5 \text{ mm}}$
Capacity reduction factor - exp.6.4	$\Phi = 1 - 2 \times e / t = \mathbf{0.849}$
Design vertical resistance - exp.6.2	$N_{Rd} = \Phi \times t \times f_d = \mathbf{1252.9 \text{ kN/m}}$
Design vertical compressive stress	$\sigma_d = \min(F_x / t, 0.15 \times N_{Rd} / t) = \mathbf{0.026 \text{ N/mm}^2}$
Apparent design flexural strength - exp.6.16	$f_{xd,app} = f_{xd} + \sigma_d = \mathbf{0.109 \text{ N/mm}^2}$
Limit of charact. shear strength - exp. 3.1;	$f_{vk,lim} = 0.065 * f_b = \mathbf{0.676 \text{ N/mm}^2}$
Characteristic shear strength - exp.3.5	$f_{vk} = \min(f_{vko} + 0.4 \times \sigma_d, f_{vk,lim}) = \mathbf{0.16 \text{ N/mm}^2}$

Project Proposed Dwellings March Hywell		Job Ref.		C1447	
		Section		Sheet no./rev.	
		Retaining wall Section 4		2 33	
Calc. by	Date	Chk'd by	Date	App'd by	Date
TAH	27/11/2020				

Design shear strength

$$f_{vd} = f_{vk} / \gamma_{Mv} = \mathbf{0.064 \text{ N/mm}^2}$$

Library item: Masonry characteristics output

Unreinforced masonry walls subjected to lateral loading - Section 6.3

Design bending moment combination 1;

$$M = \mathbf{9.439 \text{ kNm/m}}$$

Elastic section modulus of wall;

$$Z = t^2 / 6 = \mathbf{104016667 \text{ mm}^3/\text{m}}$$

Moment of resistance of masonry - exp.6.15;

$$M_{Rd} = f_{xd,app} \times Z = \mathbf{11.1 \text{ kNm/m}}$$

PASS - Moment of resistance is more than applied design moment

Unreinforced masonry walls subjected to shear loading - Section 6.2

Design shear force

$$V = \mathbf{13.801 \text{ kN/m}}$$

Maximum compressive stress;

$$\sigma_{max} = F_x / t + M / Z = \mathbf{0.116 \text{ N/mm}^2}$$

Minimum compressive stress;

$$\sigma_{min} = F_x / t - M / Z = \mathbf{-0.065 \text{ N/mm}^2}$$

Thickness of wall in compression;

$$t_c = t * \sigma_{max} / (\sigma_{max} - \sigma_{min}) = \mathbf{507 \text{ mm}}$$

Design shear resistance - exp.6.13;

$$V_{Rd} = f_{vd} \times t_c = \mathbf{32.514 \text{ kN/m}}$$

$$V / V_{Rd} = \mathbf{0.424}$$

PASS - Design shear resistance exceeds applied design shear force

Check stem design at 1100 mm

Depth of section;

$$t = \mathbf{555 \text{ mm}}$$

Masonry characteristics

Compressive strength constants - Table NA.4

$$K = 0.550$$

Characteristic compressive strength - cl.3.6.1.2(1)

$$f_k = K * f_b^{0.7} * f_m^{0.3} = \mathbf{4.294 \text{ N/mm}^2}$$

Design compressive strength

$$f_d = f_k / \gamma_{Mc} = \mathbf{1.867 \text{ N/mm}^2}$$

Design flexural strength

$$f_{xd} = f_{xk} / \gamma_{Mt} = \mathbf{0.083 \text{ N/mm}^2}$$

Height of masonry

$$h_{wt} = h_{stem} - 1100 \text{ mm} = \mathbf{925 \text{ mm}}$$

Compressive axial force combination 0

$$F_x = \gamma_{Gf} * \gamma_{stem} * (h_{s3} * t_{s3} + h_{s4} * t_{s4}) = \mathbf{8.3 \text{ kN/m}}$$

Moment combination 0

$$M_x = \gamma_{Gf} * \gamma_{stem} * (h_{s3} * t_{s3} * t_{s3} / 2 + h_{s4} * t_{s4} * t_{s4} / 2) = \mathbf{2.1 \text{ kNm/m}}$$

Eccentricity of axial load

$$e = \max(\text{abs}(t / 2 - M_x / F_x), 0.05 \times t) = \mathbf{27.8 \text{ mm}}$$

Capacity reduction factor - exp.6.4

$$\Phi = 1 - 2 \times e / t = \mathbf{0.9}$$

Design vertical resistance - exp.6.2

$$N_{Rd} = \Phi \times t \times f_d = \mathbf{932.6 \text{ kN/m}}$$

Design vertical compressive stress

$$\sigma_d = \min(F_x / t, 0.15 \times N_{Rd} / t) = \mathbf{0.015 \text{ N/mm}^2}$$

Apparent design flexural strength - exp.6.16

$$f_{xd,app} = f_{xd} + \sigma_d = \mathbf{0.09 \text{ N/mm}^2}$$

Limit of charact. shear strength - exp. 3.1;

$$f_{vk,lim} = 0.065 * f_b = \mathbf{0.676 \text{ N/mm}^2}$$

Characteristic shear strength - exp.3.5

$$f_{vk} = \min(f_{vko} + 0.4 \times \sigma_d, f_{vk,lim}) = \mathbf{0.156 \text{ N/mm}^2}$$

Design shear strength

$$f_{vd} = f_{vk} / \gamma_{Mv} = \mathbf{0.062 \text{ N/mm}^2}$$

Library item: Masonry characteristics output

Unreinforced masonry walls subjected to lateral loading - Section 6.3

Design bending moment combination 1;

$$M = \mathbf{2.057 \text{ kNm/m}}$$

Elastic section modulus of wall;

$$Z = t^2 / 6 = \mathbf{51337500 \text{ mm}^3/\text{m}}$$

Moment of resistance of masonry - exp.6.15;

$$M_{Rd} = f_{xd,app} \times Z = \mathbf{5.16 \text{ kNm/m}}$$

PASS - Moment of resistance is more than applied design moment

Unreinforced masonry walls subjected to shear loading - Section 6.2

Design shear force

$$V = \mathbf{5.269 \text{ kN/m}}$$

Maximum compressive stress;

$$\sigma_{max} = F_x / t + M / Z = \mathbf{0.055 \text{ N/mm}^2}$$

Minimum compressive stress;

$$\sigma_{min} = F_x / t - M / Z = \mathbf{-0.025 \text{ N/mm}^2}$$

Thickness of wall in compression;

$$t_c = t * \sigma_{max} / (\sigma_{max} - \sigma_{min}) = \mathbf{381 \text{ mm}}$$

Project				Job Ref.	
Proposed Dwellings March Hywell				C1447	
Section				Sheet no./rev.	
Retaining wall Section 4				2 34	
Calc. by	Date	Chk'd by	Date	App'd by	Date
TAH	27/11/2020				

Design shear resistance - exp.6.13;

$$V_{Rd} = f_{vd} \times t_c = \mathbf{23.806 \text{ kN/m}}$$

$$V / V_{Rd} = \mathbf{0.221}$$

PASS - Design shear resistance exceeds applied design shear force

Check stem design at 1700 mm

Depth of section;

$$t = \mathbf{325 \text{ mm}}$$

Masonry characteristics

Compressive strength constants - Table NA.4

$$K = 0.550$$

Characteristic compressive strength - cl.3.6.1.2(1)

$$f_k = K * f_b^{0.7} * f_m^{0.3} = \mathbf{4.294 \text{ N/mm}^2}$$

Design compressive strength

$$f_d = f_k / \gamma_{Mc} = \mathbf{1.867 \text{ N/mm}^2}$$

Design flexural strength

$$f_{xd} = f_{xk} / \gamma_{Mt} = \mathbf{0.083 \text{ N/mm}^2}$$

Height of masonry

$$h_{wt} = h_{stem} - 1700 \text{ mm} = \mathbf{325 \text{ mm}}$$

Compressive axial force combination 0

$$F_x = \gamma_{Gf} * \gamma_{stem} * h_{s4} * t_{s4} = \mathbf{2 \text{ kN/m}}$$

Moment combination 0

$$M_x = \gamma_{Gf} * \gamma_{stem} * h_{s4} * t_{s4} * t_{s4} / 2 = \mathbf{0.3 \text{ kNm/m}}$$

Eccentricity of axial load

$$e = \max(\text{abs}(t / 2 - M_x / F_x), 0.05 \times t) = \mathbf{16.3 \text{ mm}}$$

Capacity reduction factor - exp.6.4

$$\Phi = 1 - 2 \times e / t = \mathbf{0.9}$$

Design vertical resistance - exp.6.2

$$N_{Rd} = \Phi \times t \times f_d = \mathbf{546.1 \text{ kN/m}}$$

Design vertical compressive stress

$$\sigma_d = \min(F_x / t, 0.15 \times N_{Rd} / t) = \mathbf{0.006 \text{ N/mm}^2}$$

Apparent design flexural strength - exp.6.16

$$f_{xd,app} = f_{xd} + \sigma_d = \mathbf{0.089 \text{ N/mm}^2}$$

Limit of charact. shear strength - exp. 3.1;

$$f_{vk,lim} = 0.065 * f_b = \mathbf{0.676 \text{ N/mm}^2}$$

Characteristic shear strength - exp.3.5

$$f_{vk} = \min(f_{vko} + 0.4 \times \sigma_d, f_{vk,lim}) = \mathbf{0.152 \text{ N/mm}^2}$$

Design shear strength

$$f_{vd} = f_{vk} / \gamma_{Mv} = \mathbf{0.061 \text{ N/mm}^2}$$

Library item: Masonry characteristics output

Unreinforced masonry walls subjected to lateral loading - Section 6.3

Design bending moment combination 1;

$$M = \mathbf{0.193 \text{ kNm/m}}$$

Elastic section modulus of wall;

$$Z = t^2 / 6 = \mathbf{17604167 \text{ mm}^3/\text{m}}$$

Moment of resistance of masonry - exp.6.15;

$$M_{Rd} = f_{xd,app} \times Z = \mathbf{1.61 \text{ kNm/m}}$$

PASS - Moment of resistance is more than applied design moment

Unreinforced masonry walls subjected to shear loading - Section 6.2

Design shear force

$$V = \mathbf{1.29 \text{ kN/m}}$$

Maximum compressive stress;

$$\sigma_{max} = F_x / t + M / Z = \mathbf{0.017 \text{ N/mm}^2}$$

Minimum compressive stress;

$$\sigma_{min} = F_x / t - M / Z = \mathbf{-0.005 \text{ N/mm}^2}$$

Thickness of wall in compression;

$$t_c = t * \sigma_{max} / (\sigma_{max} - \sigma_{min}) = \mathbf{254 \text{ mm}}$$

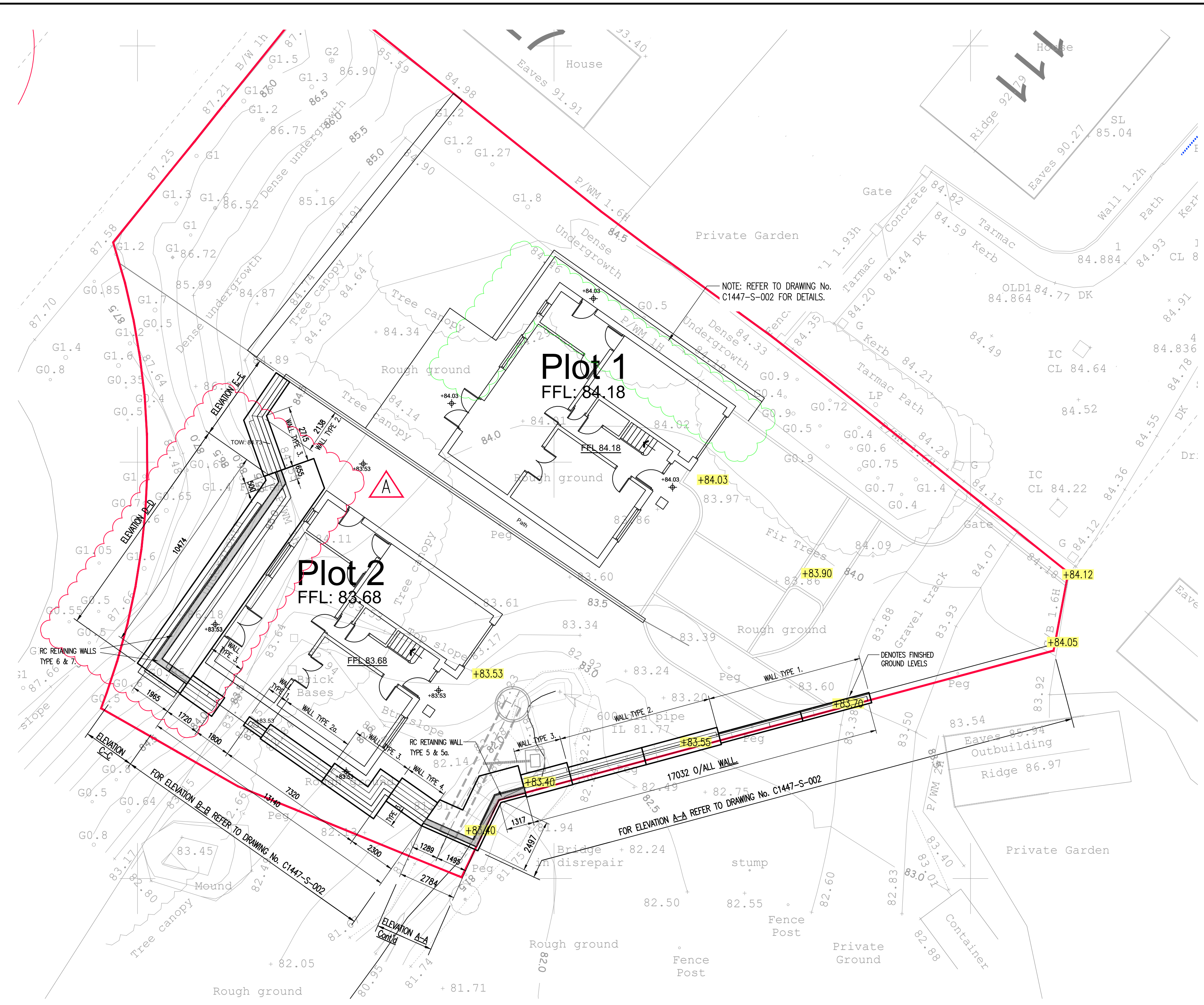
Design shear resistance - exp.6.13;

$$V_{Rd} = f_{vd} \times t_c = \mathbf{15.49 \text{ kN/m}}$$

$$V / V_{Rd} = \mathbf{0.083}$$

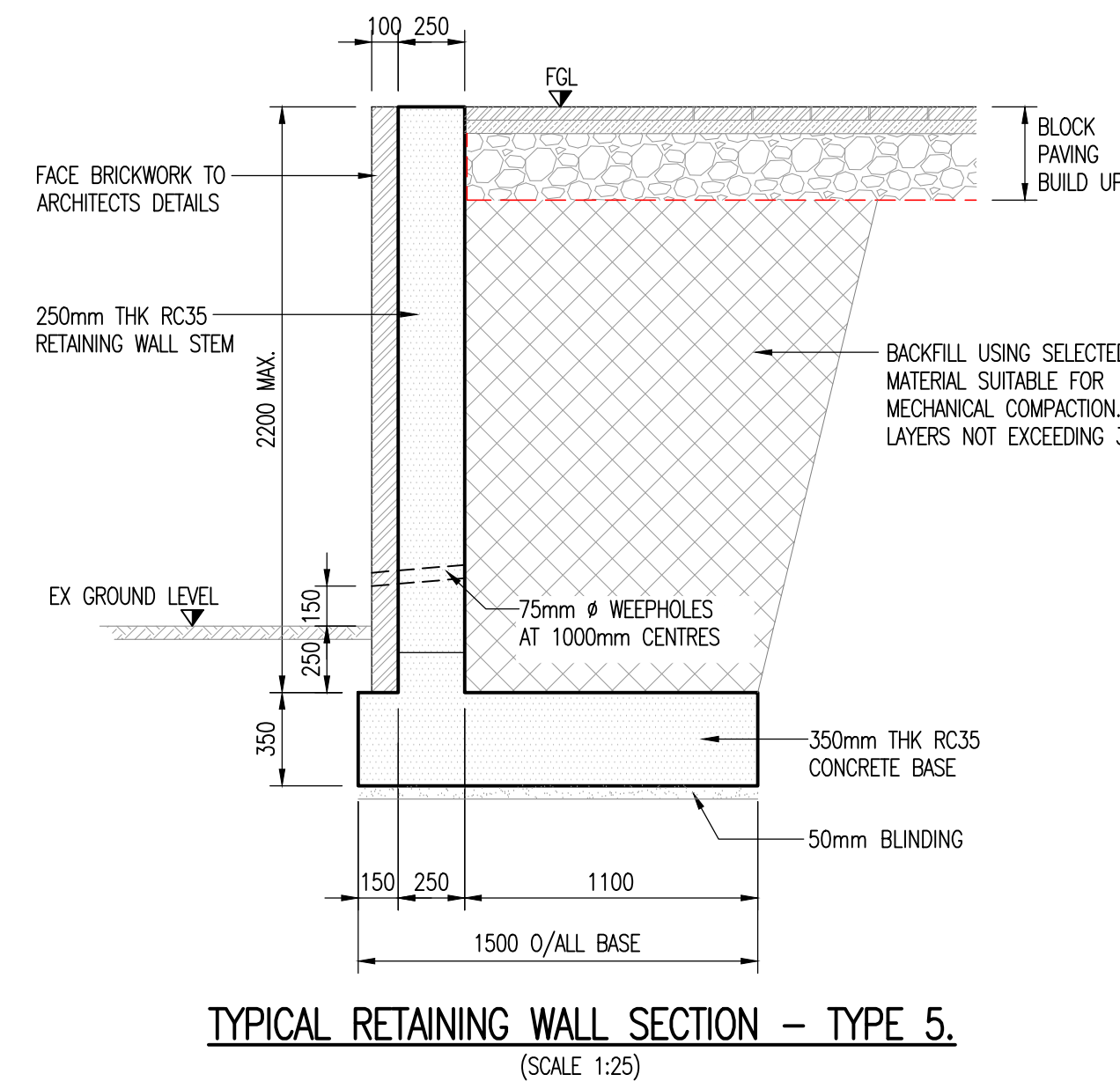
PASS - Design shear resistance exceeds applied design shear force

;

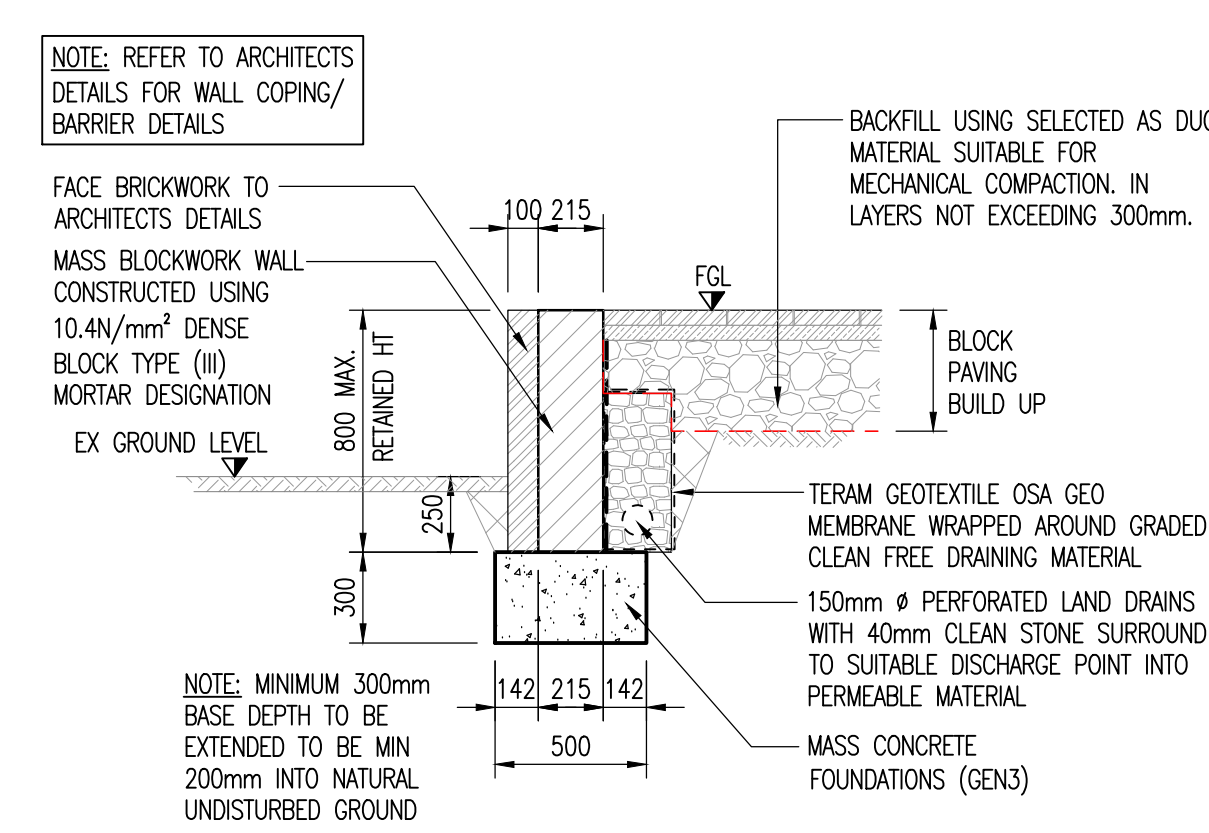


PLAN ON PROPOSED CORNER RC RETAINING WALL AND BASE
(SCALE 1:50)

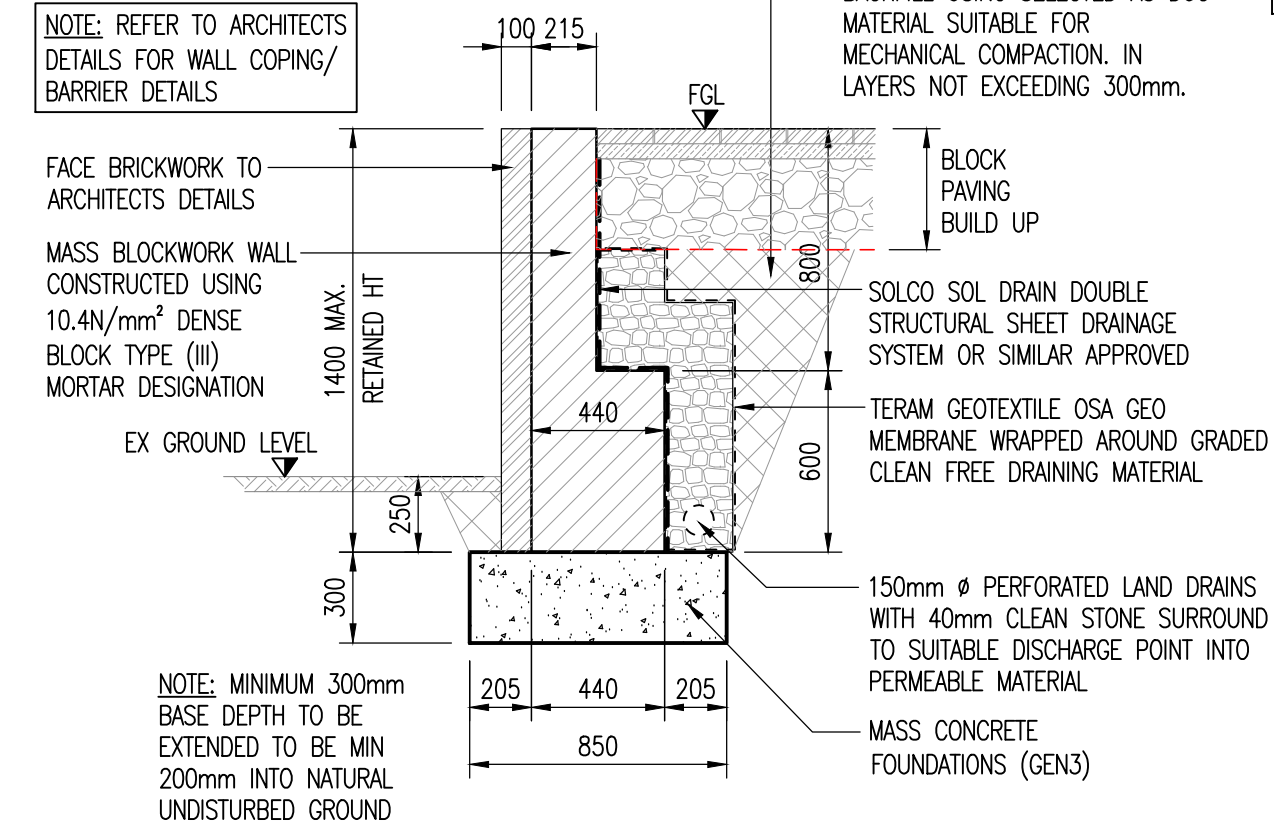
TYPICAL RETAINING WALL SECTION – TYPE 5a.
(SCALE 1:25)



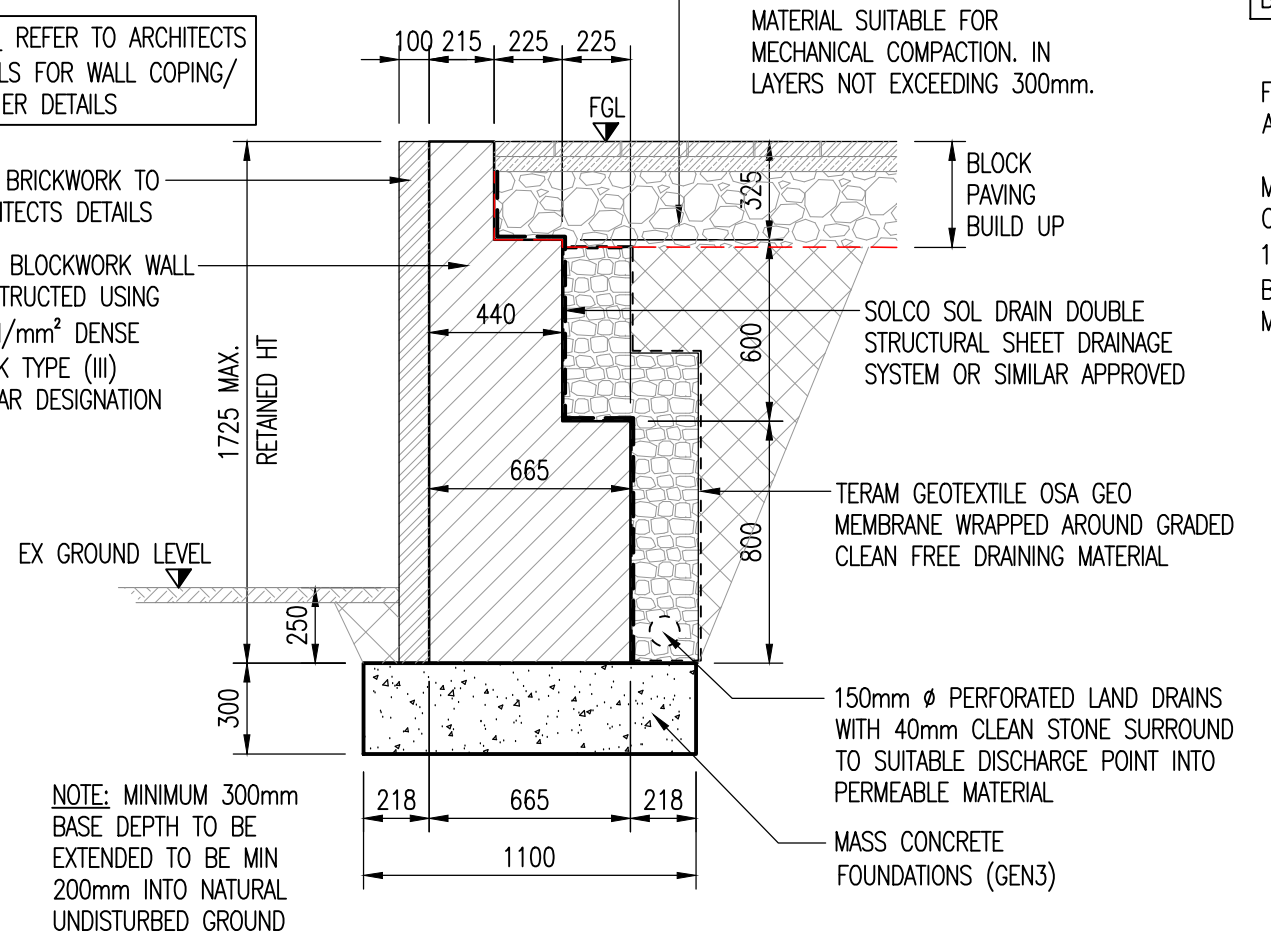
TYPICAL RETAINING WALL SECTION – TYPE 5.
(SCALE 1:25)



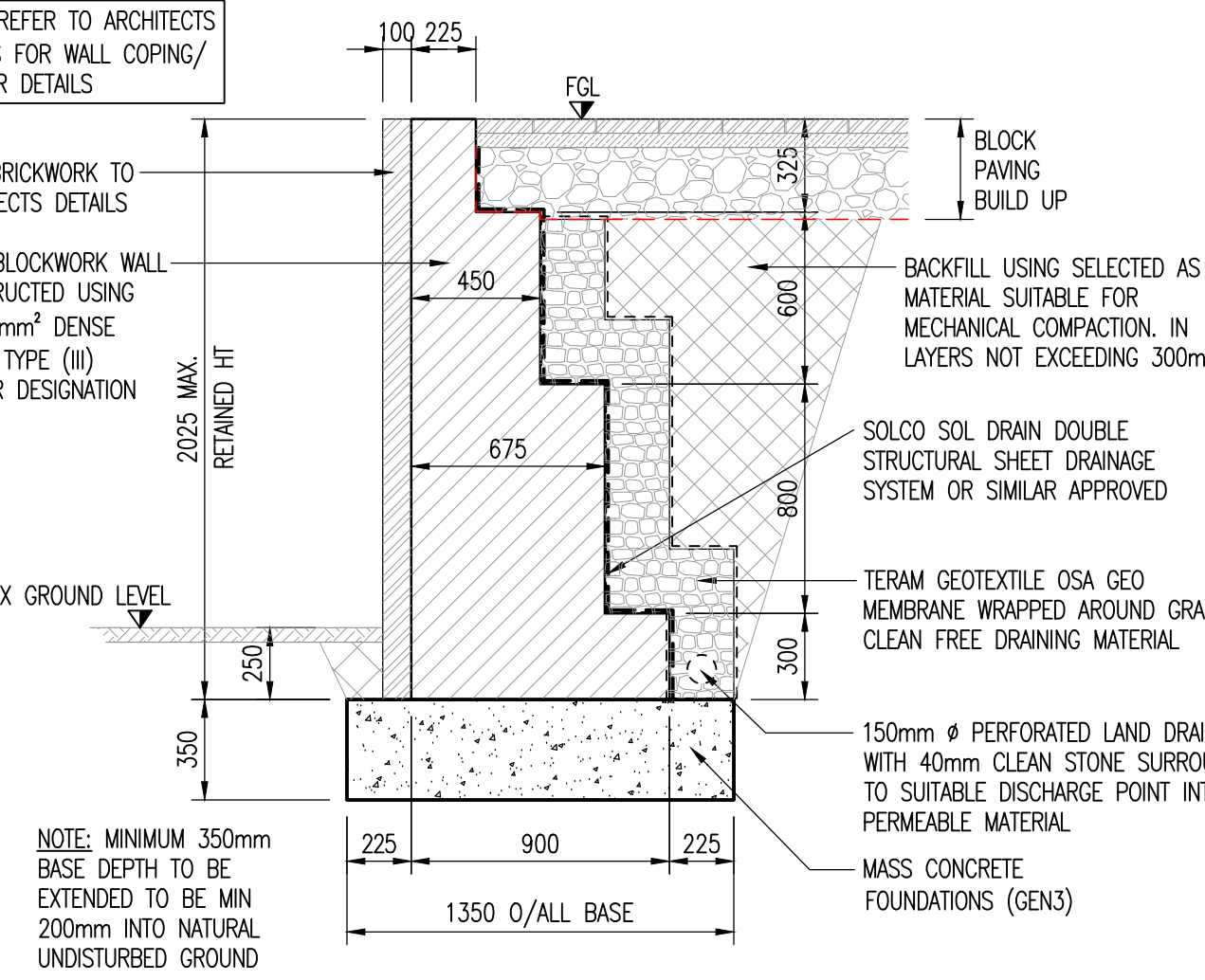
TYPICAL RETAINING WALL SECTION – TYPE 1.
(SCALE 1:25)



TYPICAL RETAINING WALL SECTION – TYPE 2.
(SCALE 1:25)



TYPICAL RETAINING WALL SECTION – TYPE 3.
(SCALE 1:25)



TYPICAL RETAINING WALL SECTION – TYPE 4.
(SCALE 1:25)

NOTES
DO NOT SCALE THIS DRAWING
CONTRACTOR TO CHECK ALL DIMENSIONS AND REPORT ALL ERRORS AND OMISSIONS TO THE ENGINEER

A	RC WALL TO REAR OF PLOT 2 AMENDED TO SUIT CLIENTS REQUIREMENTS.	SW	10.11.20
Rev.	Detail	By	Date
Revisions			

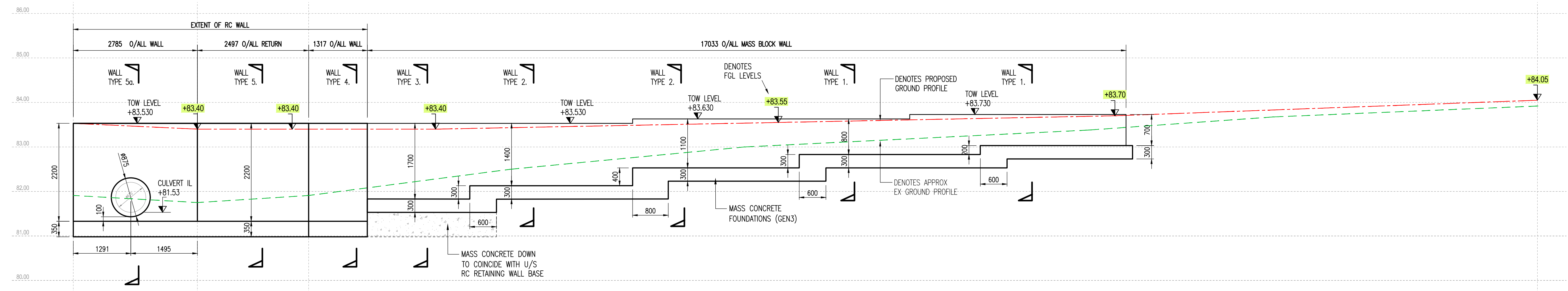
CB3 CONSULT
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Client **ASHLEY PASS**
Project **PROPOSED NEW DWELLINGS MARCH HYWELL. CILFREW NEATH**

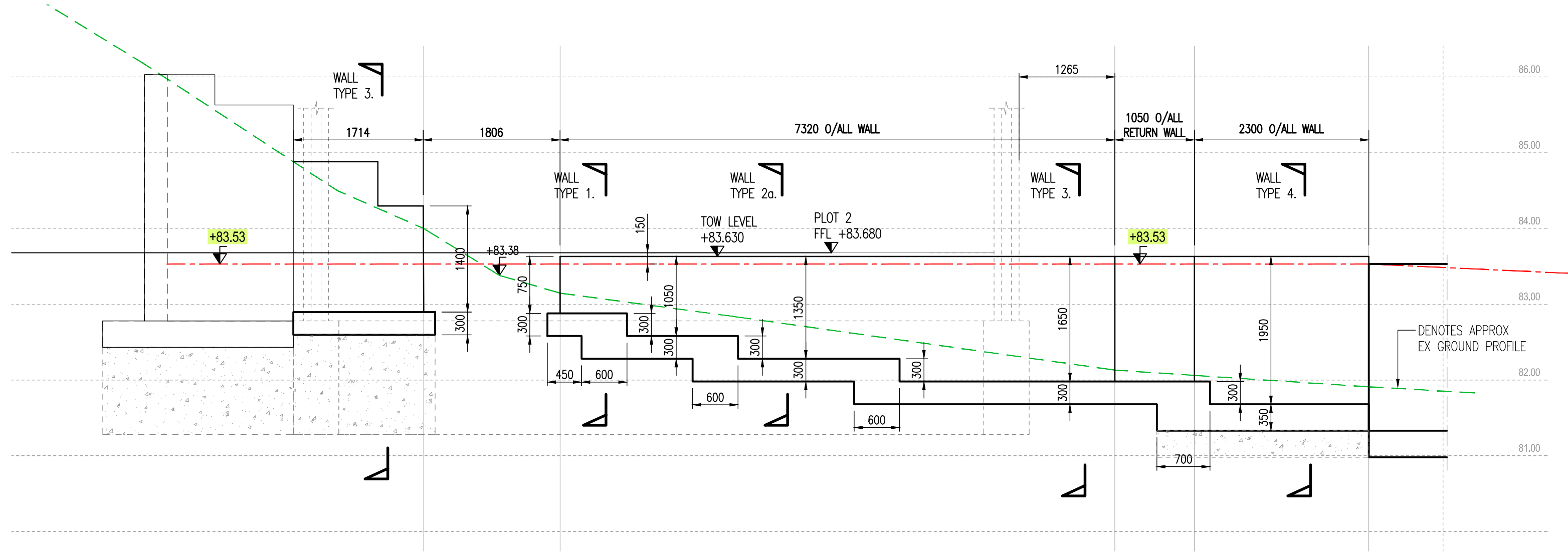
Drawing Title **GENERAL ARRANGEMENT RETAINING WALLS PLAN & TYPICAL SECTIONS**

Project No. C1447		Drawing No. S-001	
Scale AS NOTED	Checked TH	Date OCT 2020	Revision
Drawn SW	Checked TH	Sheet Size A1	

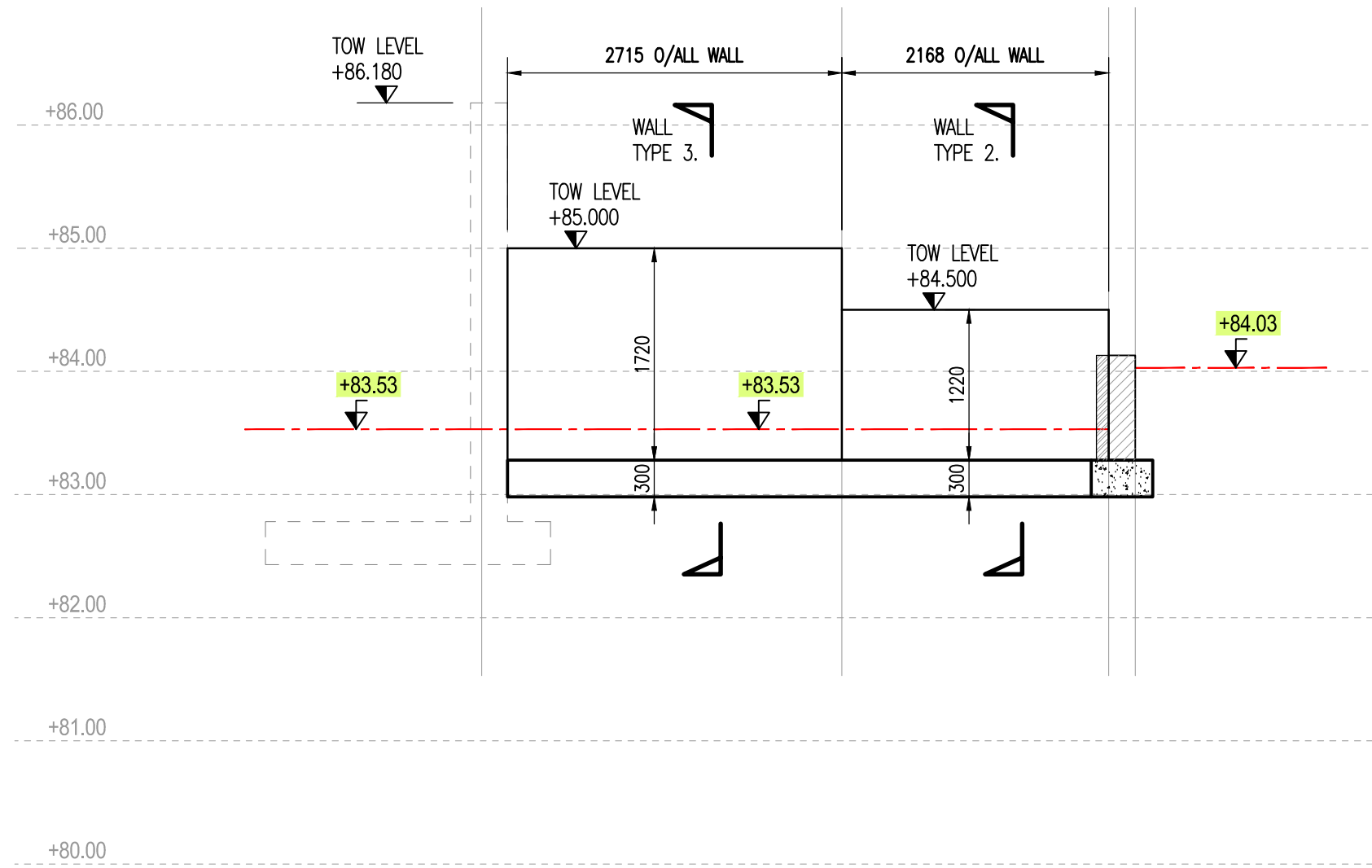
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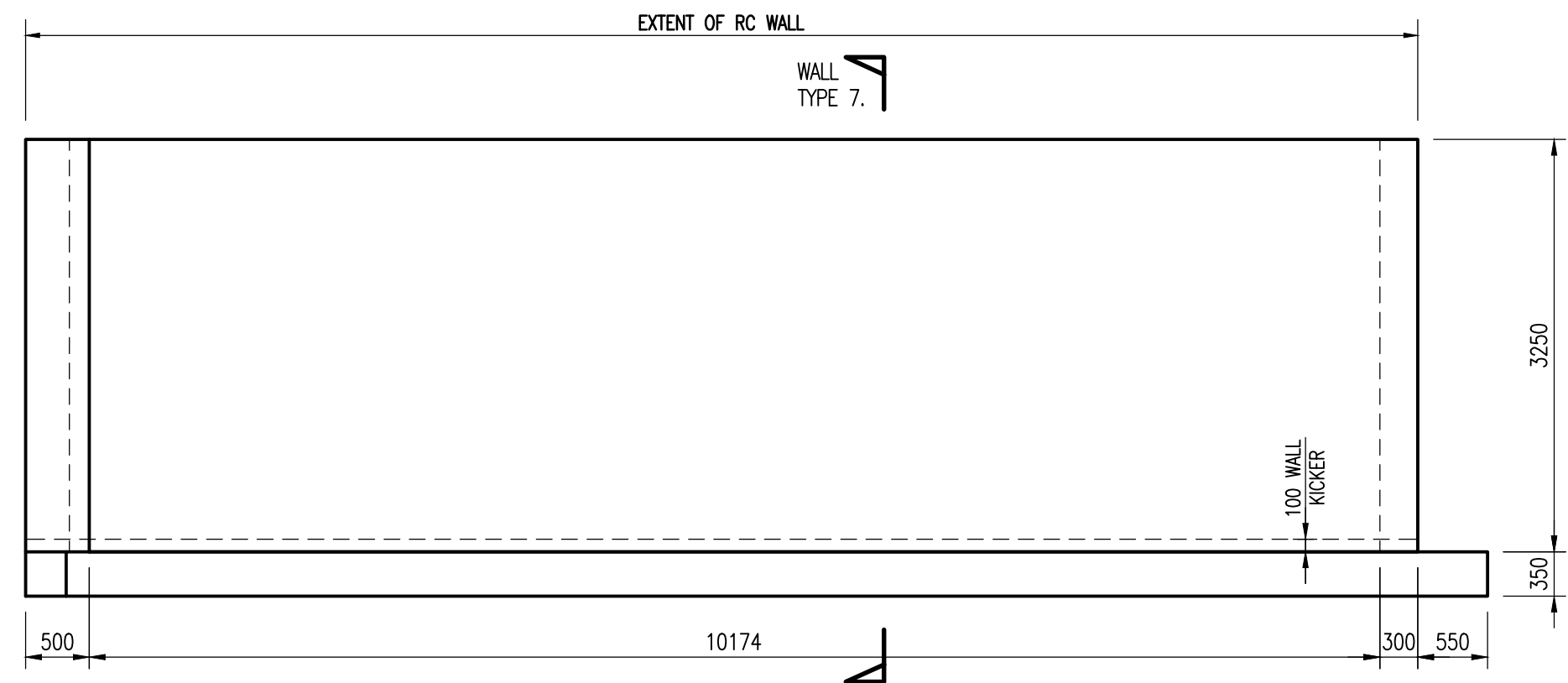
ELEVATION ALONG PROPOSED RETAINING WALL A-A
(SCALE 1:50)



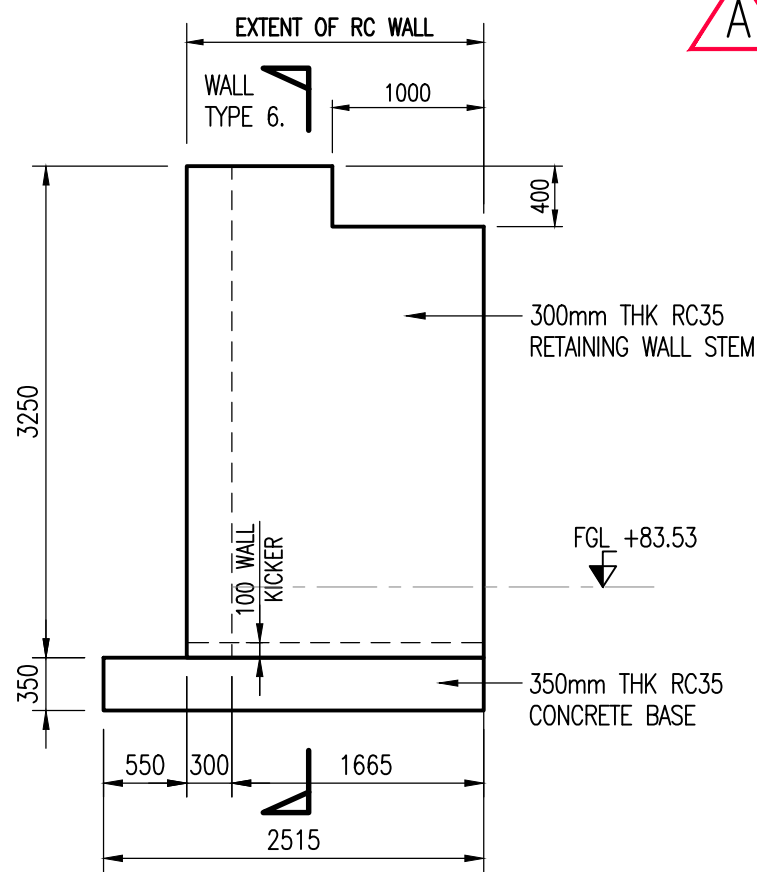
ELEVATION ALONG PROPOSED RETAINING WALL B-B
(SCALE 1:50)



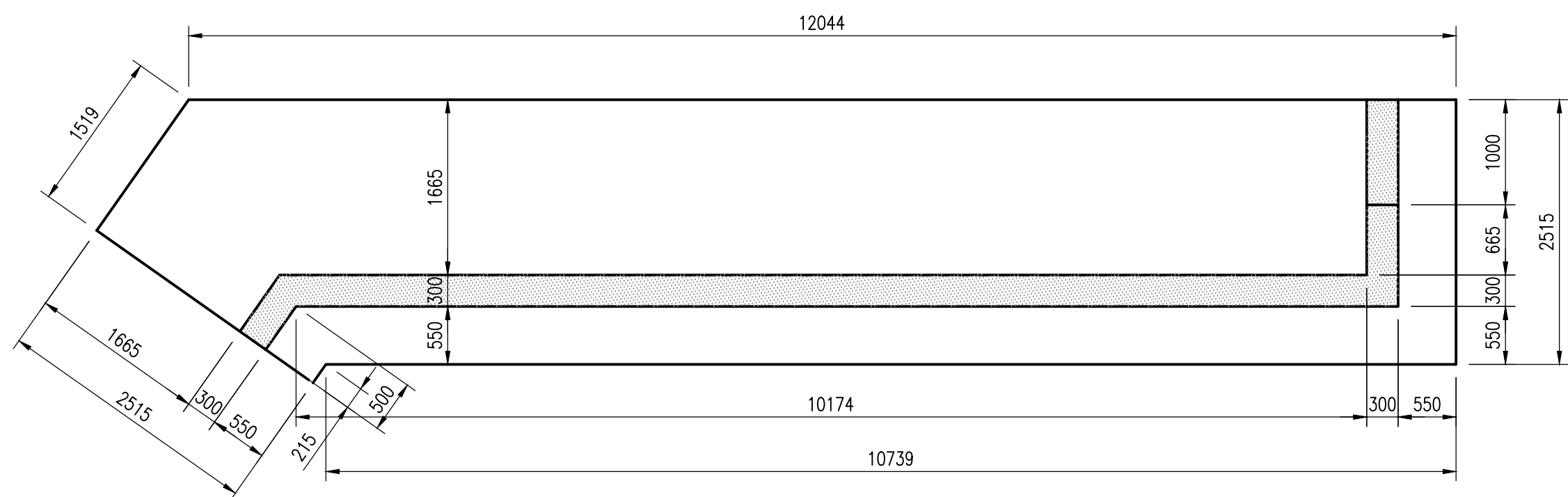
ELEVATION ALONG PROPOSED RETAINING WALL E-E
(SCALE 1:50)



ELEVATION ALONG RETAINING WALL D-D
(SCALE 1:50)



ELEVATION ALONG RETAINING WALL C-C
(SCALE 1:50)



PLAN ON RETAINING WALL REAR PLOT 2
(SCALE 1:50)

NOTES
DO NOT SCALE THIS DRAWING
CONTRACTOR TO CHECK ALL DIMENSIONS AND REPORT
ALL ERRORS AND OMISSIONS TO THE ENGINEER

A RC WALL TO REAR OF PLOT 2 AMENDED TO SUIT CLIENTS REQUIREMENTS. SW 10.11.20

Rev. Detail By Date

Revisions



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Client

ASHLEY PASS

Project

PROPOSED NEW DWELLINGS
MARCH HYWELL.
CILFREW
NEATH

Drawing Title

GENERAL ARRANGEMENT
RETAINING WALLS
TYPICAL ELEVATIONS
AND DETAILS

INFORMATION

Project No.

C1447

Drawing No.

S-002

Scales

AS NOTED

Date

OCT 2020

Revision

Drawn

SW

Checked

TH

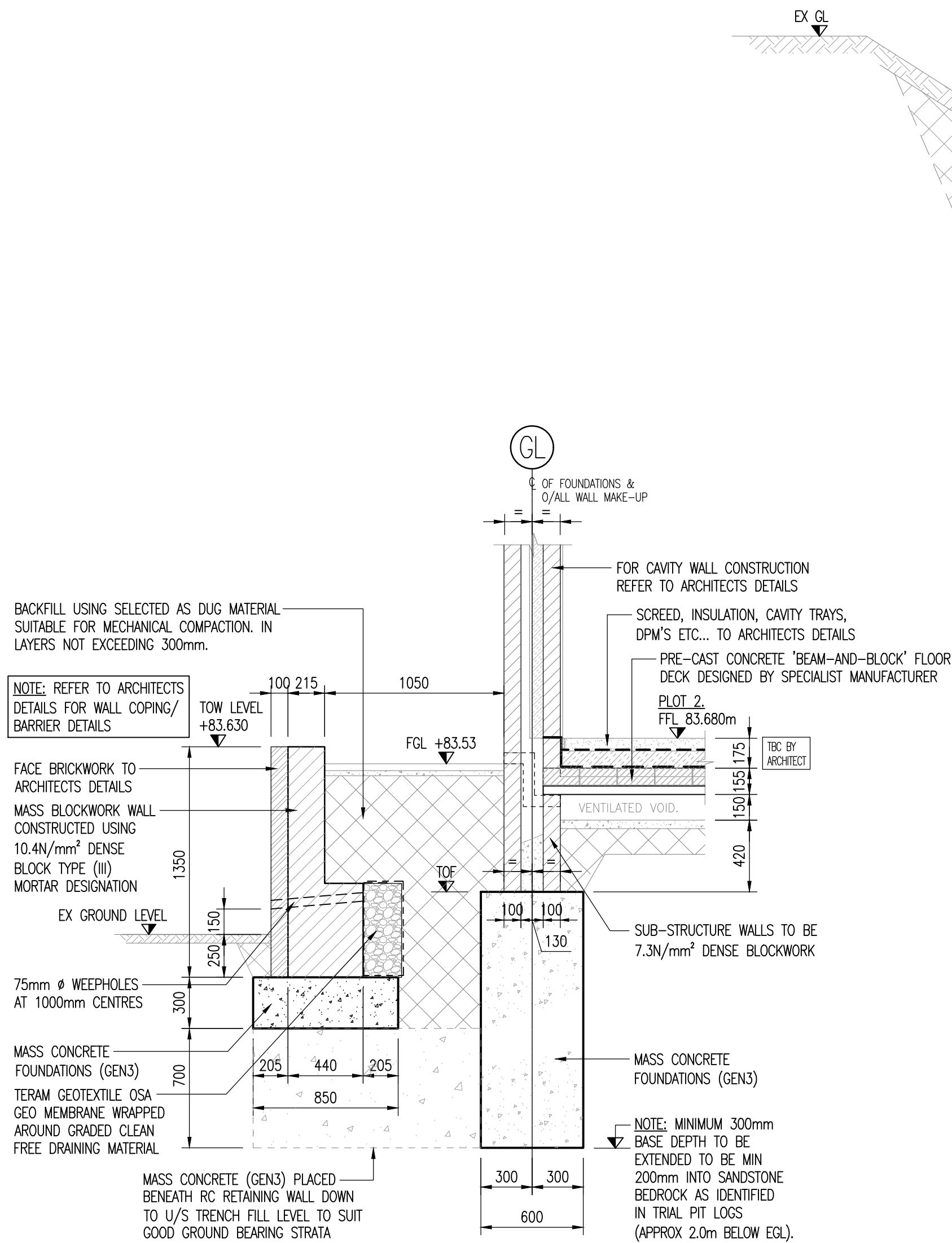
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A1

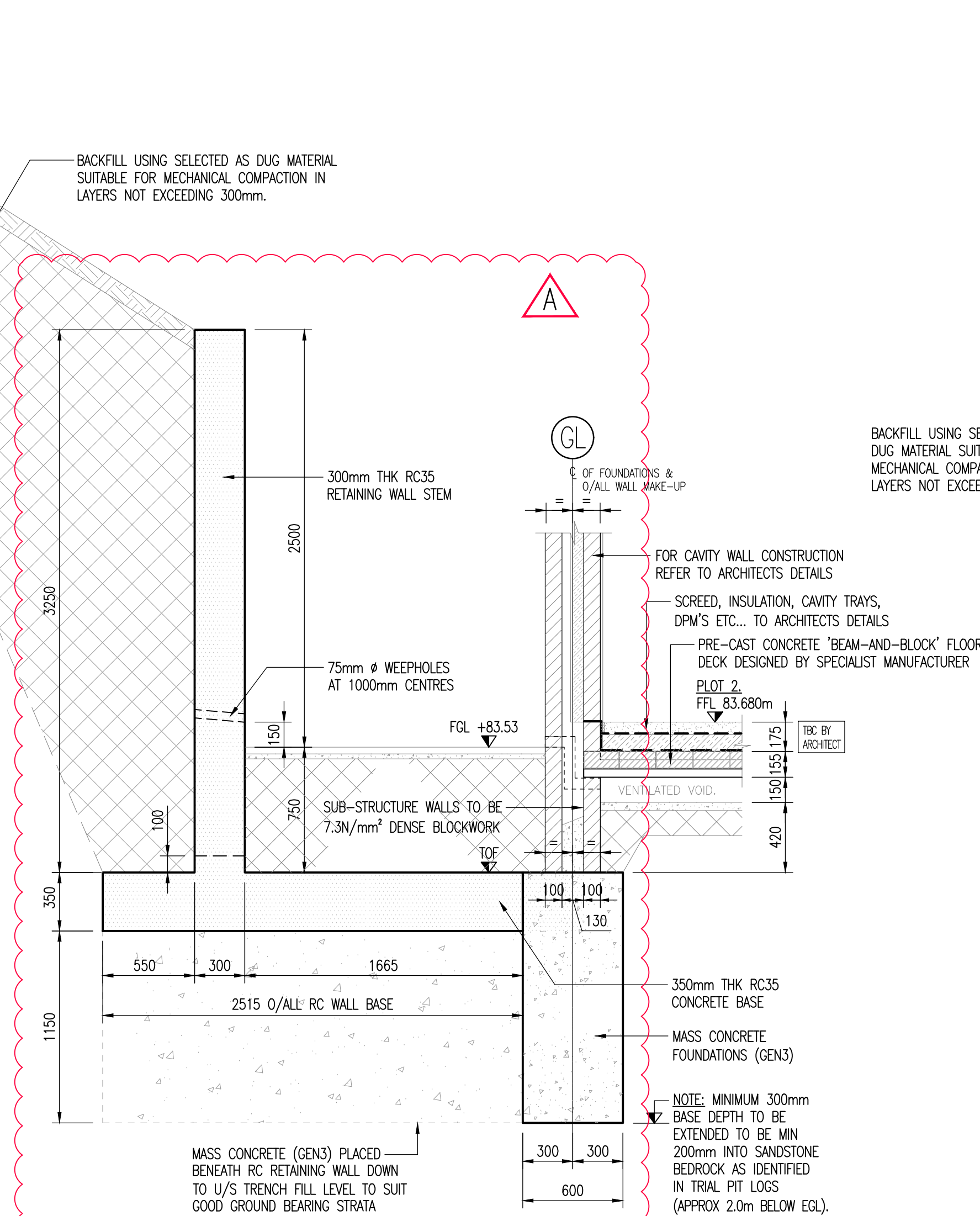
Revision

A

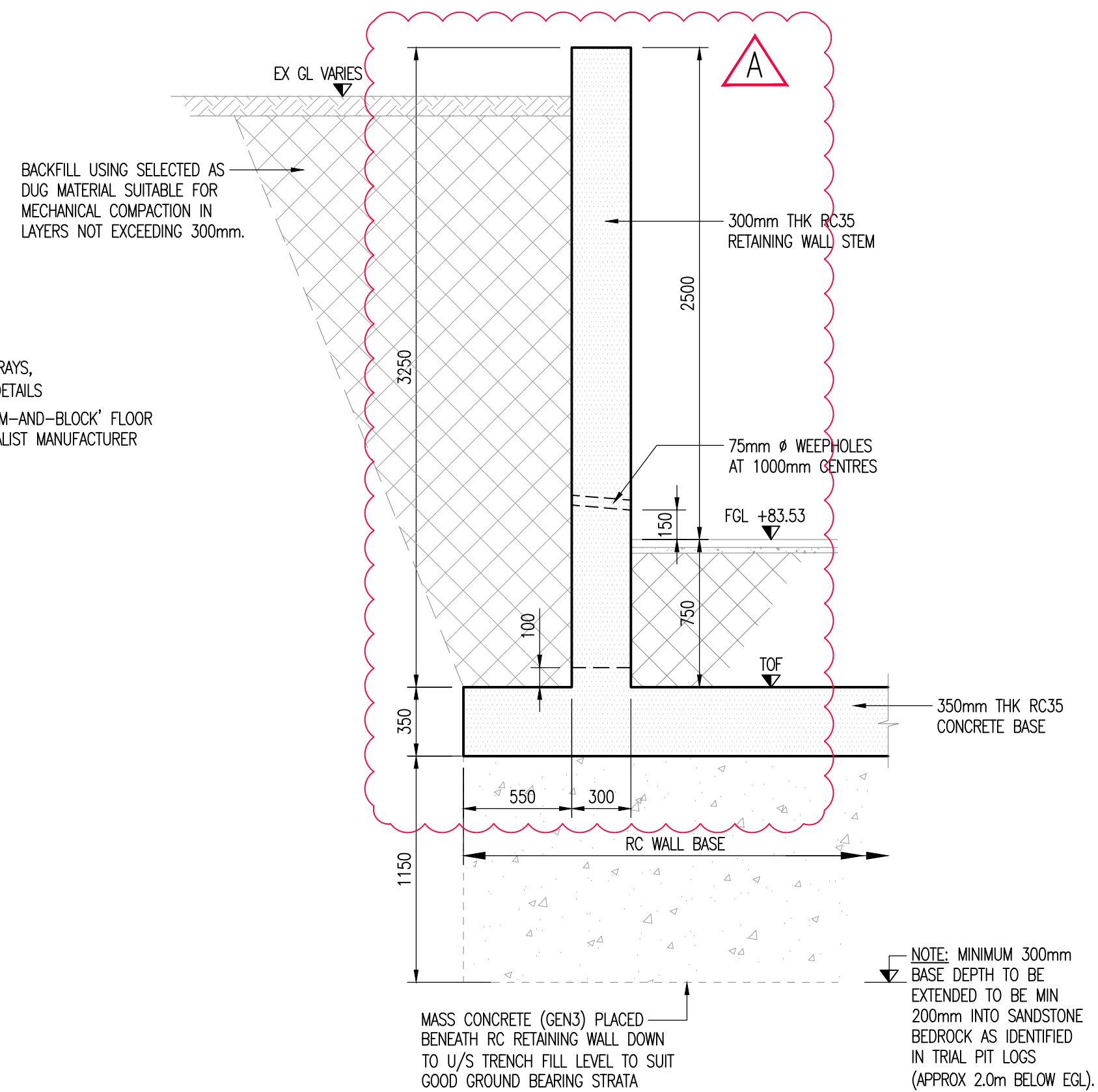
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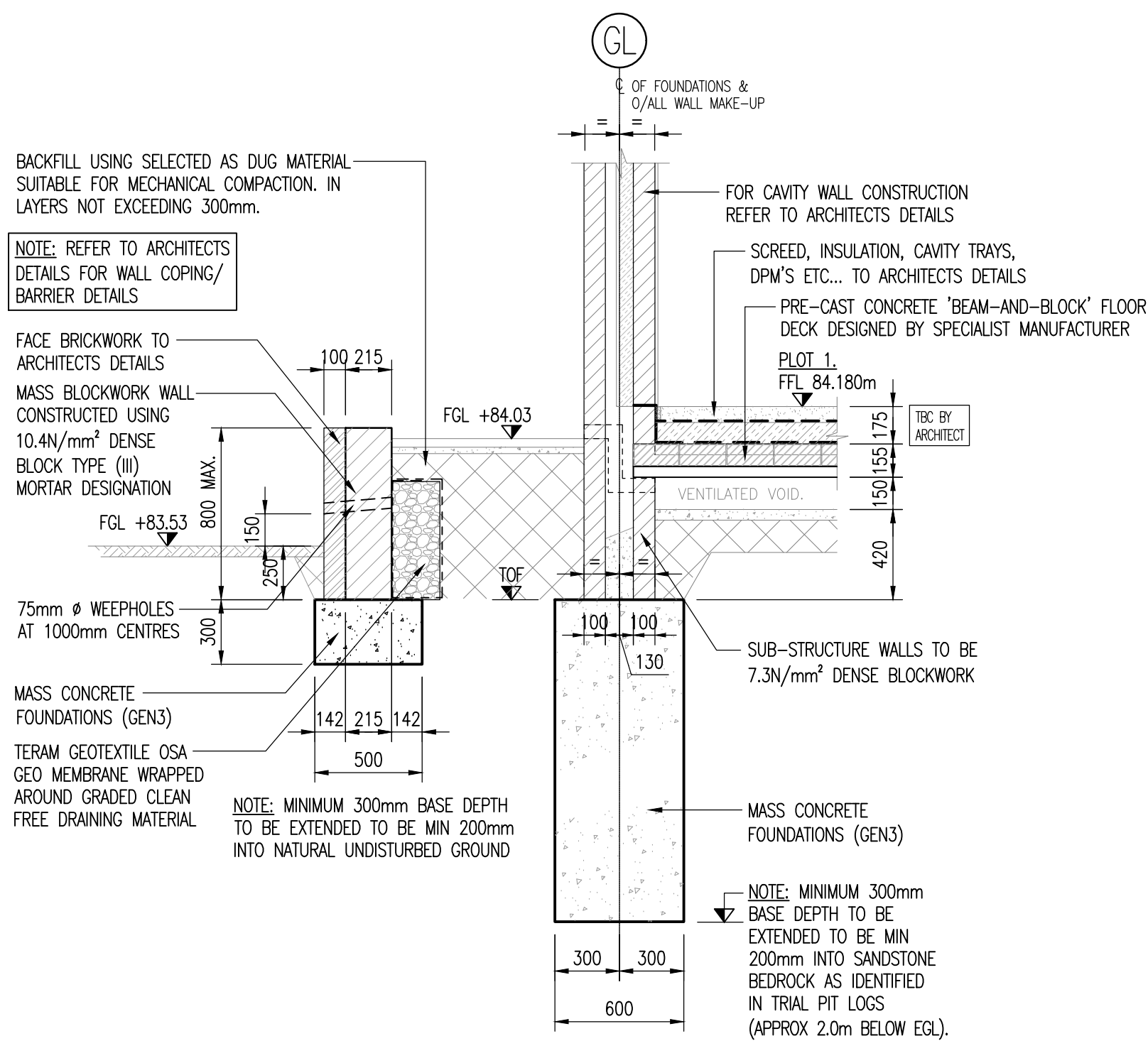
TYPICAL RETAINING WALL SECTION - TYPE 2a.
(SCALE 1:25)



TYPICAL RETAINING WALL SECTION - TYPE 7.
(SCALE 1:25)



TYPICAL RETAINING WALL SECTION - TYPE 6.
(SCALE 1:25)



TYPICAL RETAINING WALL SECTION
(SCALE 1:25)

NOTES
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A RC WALL TYPE 7 AMENDED TO SW 10.11.20
SUIT CLIENTS REQUIREMENTS.

Rev. Detail By Date
Revisions



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Project

PROPOSED NEW DWELLINGS
MARCH HYWELL.
CILFREW
NEATH

Drawing Title

GENERAL ARRANGEMENT
RETAINING WALLS
TYPICAL SECTIONS
AND DETAILS

INFORMATION

Project No.

C1447

Drawing No.

S-003

Scale

AS NOTED

Date

OCT 2020

Drawn

SW

Checked

TH

Sheet Size

A1

Revision

A

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